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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY

OF GLASGOW.

VOL. XI.—PART I.

1896-97.

GLASGOW: PUBLISHED BY THE SOCIETY,
AT ITS ROOMS, 207 BATH STREET,
1898.

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JAS. BARCLAY MURDOCH, F.R.PH.S.E.

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ERRATUM.

In the paper on *Parka decipiens*, by Messrs. Reid, Graham, and Macnair, at page 109, for *Junicus sparganium* read *Juncus* and *Sparganium*.

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GEOLOGICAL SOCIETY

OF GLASGOW.

VOL. XI.

INCLUDING SUPPLEMENT—"DRIFT OR GLACIAL BEDS OF AYRSHIRE."

1896-1899.

GLASGOW: PUBLISHED BY THE SOCIETY,
AT ITS ROOMS, 207 BATH STREET,
1900.

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No. I.—On the Occurrence of Species of the Genus *Palastræa* (M'Coy) in the Lower Carboniferous Strata of Scotland, with a Description of some New Species, and Notices of Varieties. By James Thomson, F.G.S., Hon. Member; Cor. Member of the Royal Science Society, Liége; Hon. Member of the Royal Ducal Society, Jena. With a Plate [No. I.]

[Read 11th June, 1896.]

The object of this communication is to offer evidence in favour of the recognition of the structural details distinguishing the genus *Palastræa* of M'Coy which has not been accepted by M.M. Milne Edwards and J. Haime in their well-known monograph on the Carboniferous Corals.* The facts now discovered clearly prove the accuracy of Prof. M'Coy's diagnosis of the genus, which belongs to the family Astræinæ.

The genus *Palastræa* was defined by M'Coy, in the *Annals and Magazine of Natural History*,† and subsequently in Sedgwick and M'Coy's "Palæozoic Rocks and Fossils,"‡ as follows:—"Corallum forming very large masses; terminal stars from nine lines to an inch and a half in diameter, obscurely pentagonal, bounded by narrow, rounded, or obscurely angular cellular spaces (no simple divisional walls), having from one hundred and seven to one hundred and thirty thin, jagged, radiating

* Palæontographical Society, 1852.

† 2nd series, vol. iii., p. 123.

‡ Page 110.

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lamellæ, which descend to form an oval or circular cup, and one-half of which rise again to form an oval central boss, by the edge being produced into an abrupt pali-form lobe (not distinguishable from the lamellæ); in the centre the lamellæ become indistinctly blended: *vertical section* shows the uninterrupted passage of the loose vesicular tissue, conforming to the shape of the terminal cup, in gentle curves from star to star; a very small space directly under the centre of each star having the vesicular structure almost transverse: *horizontal section* shows the alternately long and short radiating lamellæ connected (except in a small space near the centre) by fine transverse vesicular plates, and the former obscurely blended at the centre (no axis), and the irregular cellular structure intervening between the adjacent stars." The author further says—"This magnificent species is the only apparently true *Astræa* I have yet seen from the Palæozoic rocks; the numerous Palæozoic corals described under this generic title by British and foreign authors belong, for the most part, to *Stromhodes*, *Nematophyllum*, *Acervularia*, &c.; often transversely septate in the middle and having solid polygonal divisional walls to the stars—characters completely at variance with those of the recent and mesozoic Astræa, and indicating important differences in the animals and mode of increase. I propose the sub-generic title *Palastræa* for this species, as it seems to differ from the newer types in the vast number and tenuity of the lamellæ, and the great cylindrical boss in the cup from the unthickened pali-form lobes of the larger lamellæ."

The sub-genus *Palastræa* was established by M'Coy for the reception of one corallum, which, in the uncut condition, cannot be distinguished from some of the species of *Cyathophyllum* of Goldfuss,* but which, when sectioned, is separated from *Cyathophyllum* by structural details of a very pronounced character.

In *Cyathophyllum* proper a portion of the primary septa converge to the centre of the calicular fossa, where they are more or less twisted together, forming a pseudo-columella which is usually elevated and forms a more or less central boss in the calicular fossa; their inner ends rest upon a system of minute tabulæ occupying the centre of the corallum, and are externally

* "Petrefacta Germaniæ," vol. i., p. 54.

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bounded by the wall or epitheca. While in the genus *Palastræa* there is no epithecal covering, the septa are bounded by a zone of vesicular tissue, are irregular in their outward extension, and more or less merge and become absorbed in the zone of vesicular tissue which environs the corallites; towards their inner ends a portion extends to the centre of the calicular fossa, unites with the septa from opposite directions, and presents a series of vertical plates extending from the inferior to the superior extremity of the corallum; each is united by delicate interseptal dissepiments, which might be mistaken for a central lamellar area. When well-preserved specimens are examined the central area is shown to be formed by the union of the inner ends of a portion of the primary septa. These are characters which, if there were no other structural details, are sufficiently pronounced to warrant generic distinction, but the presence of the cellular tissue which environs the septa, and the absence of the epithecal covering, clearly remove the series from all existing genera.

I have one species of *Cyathophyllum* from Petershill, Bathgate, Linlithgowshire, in which the epitheca is partially absorbed and represented by an extremely delicate irregular wall; also a large slab from Corwen, Wales, in which the epithecal tissue is crushed outwards, and, at the union with the endothecal tissue of neighbouring corallites similarly crushed, presents a more or less crenulate pseudo-wall, rudely defining the irregular boundary of each corallite. In each a portion of the primary septa is more or less fasciculate near the centre of the calicular fossa, and the central septum of each fascicule converges to the centre; there they are more or less twisted and elevated, and rest upon the minute tabulæ which fill in the central area of the corallum. The latter are clearly modified species of *Cyathophyllum*, and indicate a departure from, and mergence into, other generic conditions. This demonstrates that here, as in all the groups which have been examined by me, there is a constant and persistent series of modifications, minute in some forms, but sufficiently pronounced to warrant us in regarding such modifications as more or less due to the environments, or to the inherent tendency to evolve from generic conditions into others more or less closely allied, which will only be demonstrated when our knowledge of this group of organic remains is more complete.

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The presence of several forms which must be included in the genus *Palastræa*, in the Lower Carboniferous strata of Scotland, is thus placed beyond doubt. While in some of the corallites the septa all but meet in the centre, in others they are united, as referred to above, clearly showing the difficulty of distinguishing species from varieties. There are certainly four or five groups of species, and some varieties, sufficiently dissimilar from all the species of *Cyathophyllum* to warrant generic definition. There are, however, several structural characters which have not been referred to by M'Coy. I am therefore induced to notice in detail what seems to warrant generic identity, which is all the more desirable from the fact that M'Coy considered that only structural characters warrant sub-generic definition. Milne Edwards and J. Haime did not accept *Palastræa carbonaria* of M'Coy at all, but classed it with *Cyathophyllum parricida*. After a careful examination of a number of specimens, I am disposed to regard the series as having generic distinctions, which may be defined as follows:—

PALASTRÆA (M'Coy).

Corallum compound, and frequently found to occur in masses of considerable dimensions. Development by lateral gemmation; calices variable, hexagonal, and heptagonal, and more or less exsert near the centre of the calicular fossa. Margins of the calices sharply exsert where the vesicular tissue of neighbouring corallites unites and presents an elevated ridge or spurious wall. In a transverse section the intervening spaces are occupied by a zone of vesicular tissue which externally is more or less mammilated or pseudo-cænenchyma. There is no true divisional wall.* The septa are variable in their extension, fusiform, and bilaminate in the centre, and inclined stereoplasm unites the laminæ. The calices are somewhat concave till near the

* This remarkable cellular tissue environing the septa being new to me from British strata, and not having observed anything similar in the collections I had examined in Paris, Belgium, Canada, and the U.S. of America, I was induced to forward proofs of the engravings (which are facsimiles) to no less an authority than Prof. Gustave Lindström, Stockholm, requesting him to examine them. At the same time I asked whether he had discovered similar structural details in his world-wide experience. In reply, Prof. Lindström pronounced the structure to be new to him, and that he believed it to be of generic value. Corroborated by such an eminent authority, I have no hesitation in testifying to the accuracy of Prof. M'Coy's diagnosis.

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endothecal ring: there the septa are slightly elevated, and more or less concave in the centre of the fossa; near the inner ends the primary septa are fasciculate, and a portion of them unite with septa from opposite directions in the centre of the fossa; these in a longitudinal section present a series of lammellar plates extending uninterruptedly from the calicular fossa to the inferior extremity of the corallum, and are united by interseptal dissepiments which might be mistaken for the lamellæ of the columellarian boss developed in a large number of genera and species found in the Carboniferous system. Their outer margins are irregular in their outward extension and frequently curved, and there merge and absorb with the vesicular tissue that bounds the corallites. There are primary and secondary septa united by interseptal dissepiments: these in a longitudinal section are exposed as irregular convex cellular tissue, with the convexity inwards and pointing upwards. A fossula is present.

PALASTRÆA M'COYII, *sp. nov.*, Thomson.

(Plate I., fig. 1.)

Corallum compound, and in large masses; epitheca wanting, corallites environed by irregularly disposed cellular tissue; septa delicate, bilaminate in the centre, united by inclined stereoplasm, thin and sinuous near the outer extremity, absorbed in the vesicular tissue which environs the corallites, and thin inwards from the endothecal ring. In a corallum 30 millimetres in diameter there are 46 primary septa, alternating with an equal number of secondary septa, which, from the inner endothecal ring, are delicate, and more or less fasciculate. The central septum of each fascicule extends to the centre, unites with the septa from opposite directions, uninterruptedly extends from the inferior to the superior extremity of the corallum, and is united by rectangular interseptal dissepiments. A septal fossula is present, but of irregular dimensions, and the septa which extend into it are irregular in their extension. *Palastræa M'Coyii* differs from *P. carbonaria* (M'Coy), in the septa not being so numerous in proportion to the size of the corallum, and in being without the external jagged character described by M'Coy.

This is the largest species I have discovered in Scotland. It is found in Petershill Quarry, Bathgate, Linlithgowshire, in large masses, about 40 feet above the basement marine limestone, and

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I have great pleasure in naming it in honour of Prof. M'Coy, the discoverer of the genus.

PALASTRÆA VERMIFORMIS, *sp. nov.*, Thomson.

(Plate I., fig. 2.)

Corallum compound, bounded by irregular vermiform cellular tissue; no epitheca; septa irregular in their extension, and absorbed in the vesicular tissue which bounds the corallites. A fossula is present, but often indistinct, and a small primary septum of varied extension passes into it. In a corallum 12 millimetres in diameter there are 30 primary septa, alternating with an equal number of secondary septa, each united by rectangular interseptal dissepiments. The septa are bilaminate, and the lamellæ are united by inclined stereoplasm. They are irregular in their inward extension, a portion of them coalesce, are more or less fasciculate, and merge into the centre; there they unite with septa from opposite directions, which, in a well-preserved specimen, are shown extending from the inferior to the superior extremity of the corallum, and each are united by rectangular interseptal dissepiments. In some of the corallites the septa do not reach the centre, and in this respect resemble the central area of the genus *Campophyllum*. From the latter this species differs in the absence of the tabulæ in the centre of the corallum, which indicates a transitional condition from the Campophyllidæ into the genus *Palastræa*. Some of these, if sectioned individually, would be referred to the former genus. The environment of the corallites by the cellular tissue clearly establishes the identity of the group, and demonstrates that there is a constant and persistent tendency to evolve from, and to merge into, allied groups. The development is by latro-calicular gemmation. This interesting species is distinguished by the small size of the corallites, by the vermiform tissue which bounds the corallites, and by the greater space between each.

It is found at Petershill Quarry, Bathgate, Linlithgowshire, overlying the basement bed of the marine limestone.

PALASTRÆA MICROCELLULARIA, *sp. nov.*, Thomson.

(Plate I., fig. 3.)

Corallum compound, environed with minute cellular tissue, and there is no divisional wall. The septa are irregular in their extension, bilaminate, and the laminæ are united by delicate

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inclined stereoplasm; they are cellular in their outer extremities, and merge into the cellular tissue which bounds the corallites. In a corallum 10 millimetres in diameter there are 32 primary septa, alternating with an equal number of secondary septa, united by rectangular interseptal dissepiments in the inner half of their length; while towards the outer ends they are more or less elongated, and are incorporated with the cellular tissue which environs the corallites. The primary septa are united into fascicules, and the central septum of each fascicule unites with septa from opposite directions in the centre of the calicular fossa. In a longitudinal section, the inner ends are shown extending uninterruptedly from the superior to the inferior extremity of the corallum, and are united by minute dissepiments, presenting in longitudinal section a vesicular axis. The convex interseptal vesicular tissue extends to the cellular tissue environing the corallum, the convexity pointing upwards and inwards, and arranged in oblique rows. A fossula is present, but is indistinct; a primary septum of shorter length extends into it. Upon the whole, this species is readily distinguished from the other species by the density of the minute cellular tissue which environs the corallites, and by the irregularity of the septa.

It is found at Blackridge, Dumfriesshire, about 4 feet above the lowest marine Carboniferous limestone, associated with the genus *Phillipsastræa*. The specimens from this locality are all of a dull chocolate-red colour, from the presence of protoxide of iron floated into the old sea-margin.

PALASTRÆA MICROCELLULARIA, *sp. nov.*, Thomson.
(Plate I., fig. 4.)

A variety with the septa less dense than the type. In a corallum 13 millimetres in diameter there are about 32 primary septa, alternating with an equal number of secondary septa. The distribution of the vesicular tissue which environs the corallites is not so minute, and the outer extremities of the septa are less vesicular than the type, which, if examined singly, might be ranked as a distinct species, but in a connected series can only be regarded as a variety. This demonstrates clearly the inherent tendency to evolve from, and to merge into, other specific conditions. A fossula is present; a primary septum of shorter length extends into it.

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It is found at Blackridge, Dumfriesshire, a few feet above the basement marine limestone.

PALASTRÆA HUNTERI, *sp. nov.*, Thomson.
(Plate I., fig. 5.)

Corallum compound; septa bilaminate, and inclined stereoplasm unites the laminæ; septa delicate, more or less fasciculate at their inner extremities, and unite with the septa from opposite directions in the centre of the calicular fossa; delicate at their outer extremities, curve, and are more or less incorporated with the cellular tissue which environs the corallites. In a corallum 14 millimetres in diameter there are 35 primary septa, alternating with an equal number of secondary septa. A fossula is present, but minute and indistinct. Upon the whole, this species may be recognised by the delicate septa, the rectangular interseptal dissepiments, and the less dense condition of the cellular tissue in the environments of the corallites.

It is found at Petershill, Bathgate, Linlithgowshire, in the thin beds of limestone about 6 feet above the basement marine Carboniferous limestone. It gives me great pleasure to name it in honour of Dr. J. R. S. Hunter (now Hunter-Selkirk) of Daleville, one of the Society's honorary members, who has devoted so much time and money to the preparation of sections of the corals of the Carboniferous system.

PALASTRÆA HUNTERI, var. YOUNGIANA, *sp. nov.*, Thomson.
(Plate I., fig. 6.)

Corallum compound; corallites environed with loose cellular tissue; no division wall. In a corallum 15 millimetres in diameter there are 38 primary septa, alternating with an equal number of secondary septa, which are united by rectangular dissepiments. Septa bilaminate from the inner endothecal ring to where they are incorporated with the cellular tissue which bounds the corallite; inclined stereoplasm unites the laminæ; the septa are fascicular near the inner extremities. In some corallites a septum from each fascicule unites in the centre with the septa from the opposite directions; while in others they stop short of the centre, and leave a minute open space in the centre of the calicular fossa. This indicates their transitional tendency and mergence from the structural character of the more complex forms of the genus *Campophyllum* into the structural details of

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the genus *Palastræa*. A fossula is present, and a shorter primary septum extends into it. While the septa are more numerous, and the vesicular tissue which environs the corallites is less dense, yet, upon the whole, we can only regard this form as demonstrating its varietal affinity and mergence into more pronounced species.

It is found at Blackridge, Dumfriesshire, in the thin beds of limestone which overlie the lowest bed of marine Carboniferous limestone in Scotland. I have much pleasure in naming it in honour of Mr. John Young, LL.D., F.G.S., an old and esteemed friend of Dr. Hunter-Selkirk.

As regards the structural details of those corals referable to the genus *Cyathophyllum*, they are marked with sufficient distinctness. The epitheca is well developed, variable in stoutness, more or less marked with annulations of growth, and usually circumferentially striated. The tabulæ are limited to the central area of the corallum, are closely developed, are surrounded by vesicular tissue composed of numerous layers of minute lenticular cells, which are inclined upwards and inwards and form the periphery of the calicular fossa. The septa are usually delicate; there are always primary and secondary septa, a portion of the primary ones extend inwards to the centre of the fossa, are twisted together, are more or less elevated, and rest upon the superior face of the tabulæ which fill in the centre of the corallum.

It will thus be apparent that the structural characters of *Cyathophyllum* are pronounced, and can be distinguished from all the other genera found in the Carboniferous system by (1) the presence of a system of minute, delicate tabulæ in the centre of the corallum; (2) by the extension of a broad zone of vesicular tissue extending from the inner endothecal ring to the periphery of the corallum; and (3) by the usual twisting together of the primary septa in the centre of the calicular fossa forming a spurious columellarian boss. These are distinguishing structural details which cannot be mistaken.

The structural characters of the genus *Palastræa* are so pronounced that it is a matter of surprise that their distinguishing details have so long been misunderstood. They can at all times be recognised by (1) the presence of the zone of cellular tissue or pseudo-cænenchyma which environs the corallites; (2) the irregularity of the septa in their outward extension, which curve

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at their outer ends, and are more or less confluent with the vesicular tissue that bounds the corallites; (3) the uniting in the centre of a portion of the septa, at their inner extremity, with septa from opposite directions, which, in longitudinal section, are shown extending uninterruptedly from the superior to the inferior extremity of the corallum: these are united by transverse interseptal dissepiments in the central area, which might be mistaken for the lamellæ, as shown in some of the genera in which there is a central columellarian boss; and (4) the upturned edges of the vesicular tissue at the point of union, which present a seeming wall externally, but when sectioned are shown to merge and coalesce and thus absorb the seeming wall: there is thus no true wall.

Palastræa vermiformis (Plate i., fig. 2) in some of the corallites offers a transitional tendency between *Campophyllum dicuspidophyllum* and *Palastræa*. It agrees with the latter genus in having the vesicular tissue bounding the corallites, but approximates to the former in the fact that the septa do not reach the centre of the visceral chamber in some of the corallites, but leave a small open space. While there is this point of resemblance, the structural details of *Campophyllum* are distinctly pronounced, and can never be misunderstood. In the latter there is always a thecal covering, the septa extend to the wall, and the central area is closed in by tabulæ more or less remote; while, in those corallites of *Palastræa vermiformis* in which the septa do not reach the centre, we are inclined to regard the non-secretion of a portion of the septa as being due either to external causes, or as showing a tendency to evolve from, and to merge into, other generic conditions.

It will thus be seen that, while these genera are more or less closely allied, they are separated by characters of an unusually pronounced nature. The union of the septa in the centre of the calicular fossa, and their uninterrupted extension from the fossa to the base of the corallum is of itself sufficient, if there was no other structural distinction, to separate the group from all existing genera. The seeming wall is a new departure from the ordinary development of parts, as we dimly understand such, not reducible to the antecedents, yet brought about by causes yet to be discovered; at most, we can only regard such as a co-

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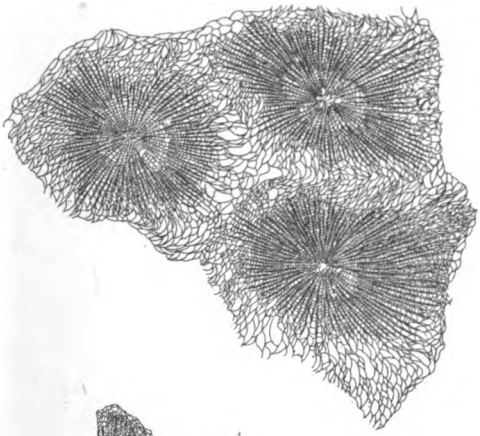
Fig. 1



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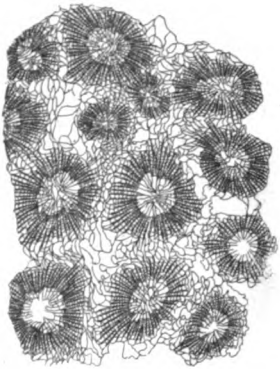

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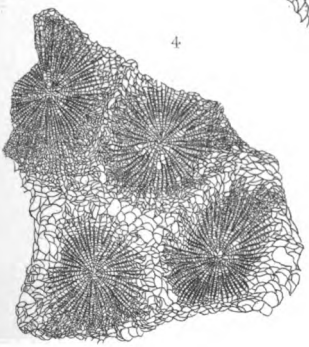

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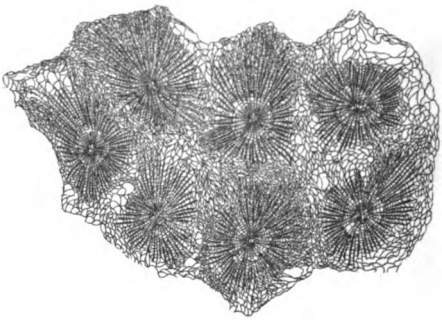

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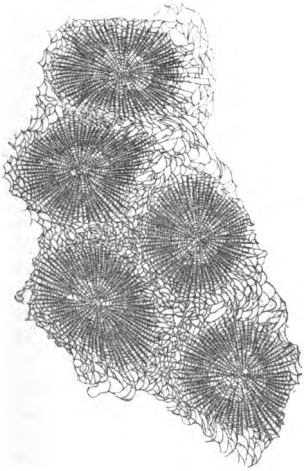

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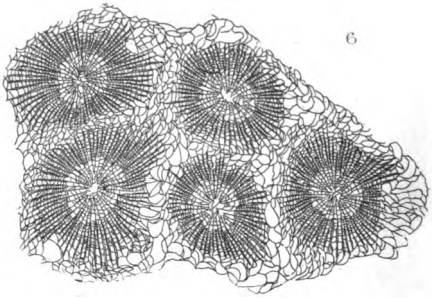

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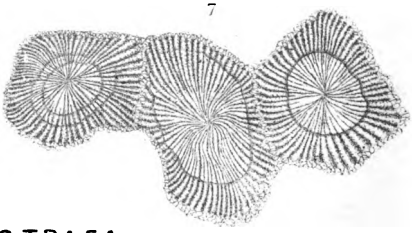

PALASTRAEA

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adaptation of the whole graduated universe of adaptable matter. Meanwhile we may record the presence of the zone of vesicular tissue which bounds each corallite, the uninterrupted extension of the septa in the centre of the visceral chamber to the base of the corallum, and the fact that there is no divisional wall between the corallites, distinctly placing the group beyond controversy, and stamping its generic identity as clearly distinct, and easily separable from all existing genera.

Explanation of Plate I.

Figure 1.—*Palastræa M'Coyii*, sp. nov., Thomson.
,, 2.—*Palastræa vermiformis*, sp. nov., Thomson.
,, 3.—*Palastræa microcelluraria*, sp. nov., Thomson.
,, 4.—*Palastræa microcelluraria*, sp. nov., Thomson.
,, 5.—*Palastræa Hunteri*, sp. nov., Thomson.
,, 6.—*Palastræa Hunteri*, var. *Youngiana*, sp. nov., Thomson.
,, 7.—*Palastræa vermiformis*, showing the external aspect of the calice.

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No. II.—On the Stratified Rocks of the Shore-line from Clachland Point to the Cock of Arran. By James Thomson, F.G.S., Hon. Member; Cor. Member of the Royal Science Society, Liége; Hon. Member of the Royal Ducal Society, Jena. With a Section [Plate II.]

[Read 11th June, 1896.*]

There is probably no part of Scotland which has attracted the attention of geologists so much as the Island of Arran, the number and magnitude of the phenomena exhibited in its comparatively limited area accounting for the stream of students of the science which yearly visits its shores. Several of our ablest observers and best geological writers have from time to time recorded the results of their investigations in the *Transactions* of various learned societies or in separate publications. Although many interesting facts have thus been published, yet the field seems so inexhaustible that each new discovery only seems to stimulate to further research.

Having long been one of the band of workers interested in the island, my principal object being the discovery of coralline remains in the Carboniferous rocks, I have, during my visits of investigation there, noted several important facts not previously recorded, and I now propose to bring these forward with some necessary remarks and explanations. Brief mention in detail will be made of the stratified rocks in their geological sequence along the shore-line from Corriegills on the south to the Cock of Arran on the north, with references, so far as practicable, to the palæontological evidence, in order to establish the stratigraphical position of the rocks in an ascending scale.

I shall give, in the first place, a list of some of the published papers relating to the geology of that part of the island with which I am at present concerned, though there may be others of importance which I have not noted. In most of these there are certain points put forward by the authors to which I must express an adverse opinion as regards the stratigraphical position of the rocks. Those writings to which I shall more particularly refer are—

* The greater part of this paper was first read to the Society on 16th January, 1875. The Section was prepared for the Meeting of the British Association held at Glasgow in 1876, and was then circulated amongst its members who took part in the Arran excursion.

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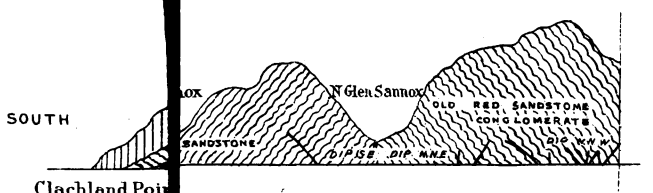

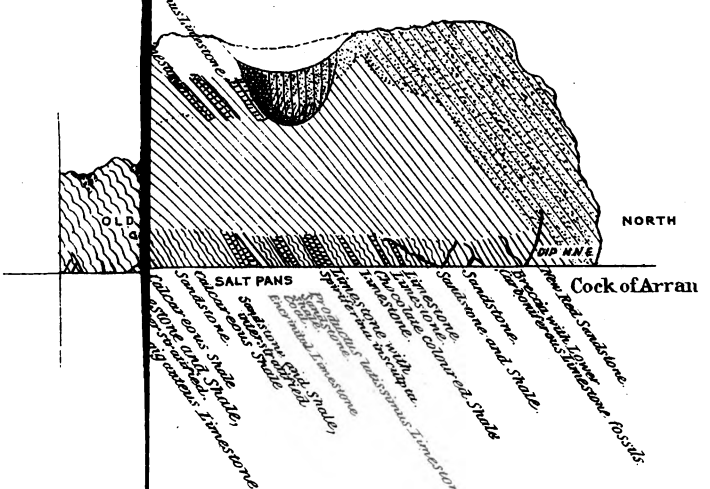
NORTH
DIP NNE
SALT PANS
Cock of Arran
Sandstone and Shale.
Limestone
Limestone with Spirifera Striata.
Limestone
Limestone
Calcareous Shale
Sandstone.
Calcareous Shale,
Sandstone and Shale,
Limestone
Limestone
Limestone

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"On the Geology of Arran," by the Rev. A. Sedgwick and Mr. R. I. Murchison, in the *Transactions of the Geological Society*, 2nd series, vol. iii., 1835.

"On the Trap Dykes of Arran," by M. L. A. Neckar, in the *Transactions of the Royal Society of Edinburgh*, 1840.

"The Geology of the Island of Arran from Original Survey," by Andrew Crombie Ramsay, Glasgow, 1841. (This work may be said to be the groundwork of various books and papers of later date.)

"Arran and other Islands of the Clyde," by James Bryce, LL.D. [1st edition], 1859. (In addition to the outcome of his own work the author has embodied the observation of others.)

"On the Occurrence of Fossil Trees embedded in Trappean Ash in Arran," by Mr. E. A. Wünsch, in the *Transactions of the Geological Society of Glasgow*, vol. ii., 1866, pp. 97-99.

"The Student's Manual of Geology," by Sir Charles Lyell, F.R.S., 1871, p. 530.

"The Geology of Arran and the other Clyde Islands," by James Bryce, LL.D., 4th edition, 1872. At p. 71, art. 35, Dr. Bryce says—"In the sandstone of the cliffs overlooking this point [Corriegills shore] we were so fortunate as to discover a true Carboniferous fossil, a species of *Orthoceras*, too imperfect for the identification of the species, ... the occurrence of which in this locality is strongly in favour of the view already advanced (arts. 8, 24) regarding the age of these sandstones." Again at p. 50, art. 24, "The rock on the shore at Invercloy is a conglomerate of the age of the coal—a member, in fact, of the coal formation. It was formerly classed as a lower member of the New Red [Sandstone], but this view cannot now be maintained. The inland cliff marking the old coast line is well seen on the Invercloy shore, and extends far up both sides of Glen Cloy."

"A New Geological Map of Scotland," by Prof. A. Geikie, 1876. (Accompanying this map, the author gives an outline of the geological phenomena of the island.)

"Travelling Sketches and Studies," by Prof. A. von Lasaulx of Breslau, Bonn, 1878. (The second chapter, devoted to Arran geology, was translated and reviewed by Mr. Wünsch in the *Transactions* of the Society, vol. vi., 1878, p. 165.)

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The section at Clachland Point where the pitchstone is exposed has been so often and so well described that I need not go over the same ground, and I shall therefore take as a starting-point the celebrated granite boulder which forms so conspicuous an object on the shore below Corriegills Farm.

The rocks which fringe the Corriegills shore—those on the north-east side of Brodick Bay, and those below the south side of Maoldon—consist of a dull greyish-red, gritty sandstone, interstratified with a brecciated conglomerate containing pebbles of grey, reddish-grey, and white quartz, intermixed with fragments of clay slate and chlorite slate. They are exposed in a terrace varying in dimensions from a few to several hundreds of feet in width, and not more than a few feet above high-water mark—a resultant of the often-recurring alternations of sea and land. This narrow plateau is the outcome of the last subsidence of the sea. A few yards further inland there is exposed a precipitous cliff, not less than 60 feet above sea-level, which has been eroded by the ceaseless action of the waves when the lower terrace was under water.

Regarding the age of the brecciated conglomerate, several of the authors above quoted have advanced theories very much at variance with each other. In 1819 Sedgwick and Murchison* defined this rock, and the brecciated conglomerate of the Cock of Arran, as belonging to the New Red Sandstone. In a subsequent paper† the same writers state that "the lower conglomerate and sandstone are referred to the Old Red Sandstone because they are inferior to beds which are supposed to represent the Carboniferous order, because they contain beds having the character of grauwacké, and also because of the presence of the cornstones (concretionary limestone) similar to those of Hertfordshire and South Wales."

Some information as to the trap dykes of the same portion of the island may be found in M. Neckar's paper noted above.

Mr. A. C. Ramsay,‡ in 1841, says—"The New Red Sandstone which succeeds the Carboniferous series in the order of superposition, extends from Glen Dubh, along the hollow and the south side of Glen Cloy. Glen Cloy is therefore partly bounded on the north by the sandstone of the Carboniferous series, which forms

* *Transactions of the Geological Society*, 1819.

† *Trans. Geol. Soc.*, 2nd series, vol. iii., 1835, p. 29.

‡ "Geology of the Island of Arran," 1841, pp. 13-14.

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the principal part of the Windmill Hill, and on the south by the New Red Sandstone. From the entrance to Glen Cloy, the same formation, often in a conglomerate form, occupies the lower hills, the rocky beach, and the high cliffs which overhang the seashore around the coast of Corriegills."

Dr. Bryce,* in 1872, says—"The encircling band of clay slate is succeeded on the east and south by a band of Old Red Sandstone, which is of irregular breadth. It begins to overlie the slate at the Fallen Rocks on the north-east coast, and occupies the shore thence to the march of Achab farm, half a mile north of Corrie. Here it retires inland, the Carboniferous formations taking its place on the shore, crosses in a narrow band to the west of Maoldon, and stretches thence continuously westward around the border of the slate to the mouth of Mauchrie Water."

In his description of the Carboniferous series he further states † that "the southern half of the island, southward of the Old Red Sandstone boundary above defined—that is, from the String road and valley of Mauchrie Water to the South End—is composed of several members of the Carboniferous series, broken through and overlaid by various igneous rocks, chiefly those of the greenstone type. The prevailing rock and substratum of the whole southern plateau is red sandstone, varying from a fine compact structure to that of a coarse conglomerate. A band of this sandstone extends also along the eastern shore northwards to Corrie; and again from the Fallen Rocks north-west to the Scriden at the northern extremity near the entrance of Loch Ranza. Subordinate to this sandstone are beds of limestone, abounding in fossils of true Carboniferous types, with beds of shale and coal, in which are found fossil plants and shells, such as characterise these strata in the basin of the Clyde. The structure, indeed, is quite analogous to that of the Clyde basin. Limestone does not occur at the base of the system, nor does it occupy any determinate place in it, but is found throughout the whole series of beds in repeated alternation with the sandstones and shales.‡ These alternations are seen in section on the seashore along the east border, on the hill-side between Corrie and Brodick, along the high grounds on both sides of Glen Cloy, Clachan Glen, Glen Scorodale, and other water channels

* "Geology of Arran," 1872, p. 13, art. 7. † *Op. cit.*, p. 14, art. 8.

‡ I am afraid that there is a mistake in the printing of this statement, as it is not in consistence with fact.—J. T.

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issuing westward; and in the Ben-leister Burn above Lamlash they descend almost to the bottom of the glen. On this ground we refer the whole of the sandstones of the southern division of the island to the Carboniferous series. The alternations in question are not seen, it is true, on the Corriegills, Whiting Bay, or Kildonan shores, nor do they appear among the sandstones of the South End; but such massive strata of red sandstone as appear along the east and south shores are common in the Carboniferous system, and form indeed everywhere its prevailing member. They are conformable to the strata inland, in perfect sequence with them, of the same mineral structure, and therefore referable no doubt to the Carboniferous system. They may thus be correlated with the calciferous sandstones of the Ayrshire coast, upper members of the system, as described by the geologists of the Ordnance Survey; but this can only be regarded as a provisional arrangement until the discovery of fossils shall give us more certain data for classification."

Prof. A. Geikie,* in his map of 1876, gave an excellent outline of Arran, and coloured the rocks of the Corriegills shore as being of Upper Old Red Sandstone age.

Professor von Lasaulx, in 1878, in the work above referred to,† classified the brecciated conglomerates of Corriegills and Brodick Bay as of Upper Old Red Sandstone age.

It will thus be apparent that these able observers are not agreed as to the age of the brecciated conglomerate so extensively developed along the Corriegills shore, and on the north-west side of Brodick Bay. The earlier authors regarded them as of New Red Sandstone age, while Dr. Bryce grouped them with Carboniferous rocks, bringing confirmatory evidence in the discovery of an *Orthoceratite* in the cliffs of the Corriegills shore. If this discovery of fossil evidence had been authentic, there could not have been a doubt regarding the age of these rocks. But there is great doubt as to it; indeed, so much so that, when I was preparing the palæontological list of the Carboniferous rocks for the last edition of his work, I suggested to Dr. Bryce that the form in question should not be included, unless its discovery in that horizon of strata could be authenticated. In reply he said that, not having collected it himself, he could not be certain it had occurred as

* "New Geological Map of Scotland."
† "Travelling Sketches," Bonn, 1878.

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stated, and that the name had better be omitted from the list. Unfortunately, however, the deletion was not made, having been overlooked when the proofs were being corrected.

Let us now briefly consider the evidence yielded by the rocks in question. Those fringing the shore of Corriegills, those on the north-west side of Brodick Bay, and north-eastwards beyond Merkland Point, consist of dull-reddish, coarse gritty sandstone, interstratified with a brecciated conglomerate, made up of pebbles of white and reddish-grey quartz, and fragments of clay slate and chlorite slate, all commingled in a dull-reddish matrix. Overlying the breccia is a series of deposits, consisting of dark-red shales, with interstratified beds of sandstone, and a pinkish-white concretionary limestone. These are overlaid by the sandstone and breccia usually found underlying the marine deposits of the Carboniferous period, as, indeed, is the order of superposition of similar rocks throughout the central valley of Scotland in their geological sequence. Sections of them are well seen at Invercloy, in Knocan burn, and near the church at the foot of Glen Shirag, where they are superimposed upon the brecciated conglomerate. In other words, these rocks more or less form the cliffs or 60-feet terrace, which is well exposed round the whole Arran coast. I think it is a fair inference to suppose that the Carboniferous rocks rested upon the underlying brecciated conglomerate, and were subsequently eroded away by the action of the sea anterior to its last elevation, the underlying sandstone and conglomerate being thus exposed around the shore-line, and the superimposed Lower Carboniferous rocks forming the summit of the 60-feet terrace.

Let us, however, compare the component parts of the brecciated conglomerate on the Corriegills shore and at Brodick Bay with those found east-north-east of Corrie, regarding which all are agreed as to their being of undoubted Upper Old Red Sandstone age. In the former the deposits consist of angular and rounded pebbles of white and pinkish-grey quartz, fragments of clay slate and chlorite slate, with occasional fragments of other rocks, all commingled in a dull-red gritty matrix. In the shore section east-north-east of Corrie we find the brecciated conglomerate is composed of precisely the same ingredients, or as nearly the same as may be accounted for by the sedimentary matter having been deposited at a different part of the old coast-line—evidence which, if we had no

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other, is of itself satisfactory in proving the contemporaneity of deposition.

Let us pause, however, before arriving at a conclusion so much at variance with the authors quoted. On the shore east-north-east of Corrie, underlying the lower marine deposits of the Carboniferous period and resting upon the brecciated conglomerate, there is a series of deposits of a widely different character. Instead of limestone containing the fossil evidence of well-marked Carboniferous types, such as are found in the superimposed beds, we have a series of red shales and sandstones interstratified with a limestone of concretionary character and pinkish-grey colour, which up till this time has yielded no evidence of organic life. Indeed, these beds form a well-marked boundary line between the lower members of the Carboniferous and the Old Red Sandstone systems. Sections of them may be examined in the before-mentioned localities, also to the north of the Fallen Rocks in Arran, near Ascog in Bute, at Millport in Cumbrae, at Tirfergus Glen near Campbeltown in Kintyre, in the Girvan Valley, in the Garple and Greenock Waters near Muirkirk, in the Logan Water, Lesmahagow, and in Todholes Burn near Stirling, as well as in many other localities which might be named. These, however, will be sufficient to show that the deposits in question found so persistent form a well-marked line of demarcation between the two periods. With such evidence we may with propriety discard as untenable the classification of Sedgwick and Murchison, Ramsay, and Bryce, and adopt that which I have given in the accompanying section (Plate ii.), the latter having been subsequently supported by Prof. A. Geikie and by Prof. von Lasaulx.

In passing north-eastwards from Brodick to Corrie a series of red sandstone rocks abuts unconformably against rocks belonging to the calciferous series, regarding which I cannot speak with so much certainty in respect to their stratigraphical position. They fringe the shore from below Maoldon to near Corrie; they have been described as belonging to the Carboniferous system, but I am not aware that fossil evidence has yet been discovered sufficient to warrant us in assigning to them a position there. It is true that at Corrie there are red marls and sandstones resting upon well-marked and characteristic members of the Lower Carboniferous rocks, and also true that similar red sandstone rocks

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are found superimposed on rocks of the same age at Dunbar, in Haddingtonshire. We have, however, in Dumfriesshire red marls and sandstones occupying a similar stratigraphical position, which are regarded as of Permian age. These rest upon rocks of exactly the same character, and with the same horizon as the Carboniferous limestones of Corrie, and therefore, in the absence of palæontological evidence, I am prevented from defining the stratigraphical position of the rocks along that portion of the Arran shore.

The rocks which next fall to be noticed in the order of succession are the Carboniferous limestones of Corrie, which have long been mined for economic purposes. The roofs of the mines present an aspect which once seen can never be forgotten, from their being studded with shells of *Productus giganteus*, the ventral valve being invariably downwards. The upper members of these limestone beds are exposed on the hillside on the north-east face of Maoldon, the dip being S.-E., at an angle of about 40°; but we do not there find all the limestones seen at Corrie, but only the upper portion of the section, or from that part of it where *P. giganteus* is less numerous and ceases to occur in the upper members.

Sedgwick and Murchison suggest that these limestone beds on the north side of Maoldon are found at their present elevation owing to an upthrow. Bryce asserts his disbelief in an upthrow, and states that none of the Corrie limestone is found upon the shore below. That it is not so found does not seem to me surprising, as the beds upon the shore may be traced overlying and resting upon the limestone at varying angles; and in proportion as we approach the disturbing agent suggested by Sedgwick and Murchison, so do the angles increase, until the junction of the granite, a little north of Maoldon, is reached. There is, however, another agent which has not been noticed, but which I believe has exerted a very important influence. Dr. Bryce refers to a dyke erupted through the Maoldon sandstone, and if we follow its trend north-east we find that it has not only upheaved the limestone, but that at the outcrop the red- and chocolate-coloured shales, interstratified with the limestone, are so much affected by the intrusive igneous rock that they are more or less converted into an impure jasper. This dyke may be traced to the north-east, although more or less concealed by drift and vegetation. It is also well exposed in the White Water, and in a small stream to the north, or about 150

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yards north-east of Maoldon, the trend being to the north-east and downwards to the east. It seems more than probable that this is a continuation of the igneous rocks on the shore north-east of Corrie, so frequently referred to, and that it is a probable agent in the tilting of these limestones to the angles at which they now lie. I have so far digressed from the shore-line, but the geological interest of this part of Arran is very great. Contiguous, in the White Water, Mr. Wünsch discovered that the granite is in contact with the Old Red Sandstone, instead of being, as stated by all former observers, in contact with the slate, as in other parts of the island (see Note at end of paper). The sandstone is rendered more or less grey in colour and quartzose in crystallization. The granite nucleus similarly affects the basement sandstones of the Carboniferous system a short distance north of the top of Maoldon.

The rocks upon the shore north-east of Corrie were referred to in discussing the age of those on the Corriegills shore, and I need not speak of them further, except simply to say that they form the upper members of the Old Red Sandstone, and that the rocks along the shore-line for about 3 miles belong to the same system; also, that in passing to the north we find the anticlinal axis exposed in North Sannox Burn, the dip being on the one side S.-E. and the other N.-N.-W. Indeed, in the bed of the stream the axis is seen in the form of a saddle-back.*

Proceeding along the shore to the north, we pass over the upturned edges of the sandstones, with interbedded breccias and conglomerates, until we come to the Fallen Rocks. This section, which has been ably described by some of the authors already quoted, is grand in the extreme. The enormous masses which have been disrupted from the parent rock strike the most unobservant eye, but there is little or no clue to the agency which has produced such a great debacle, though there is abundant evidence of igneous action in close proximity. To the north, and in contact with the brecciated conglomerate, there is a series of chocolate-coloured shales, interstratified with thin beds of sandstone and concretionary limestone, similar to those found overlying the breccias near Corrie and other previous sections referred to.

* For more detailed information on this point, consult M'Culloch's "Western Isles," 1824, and the papers by Sedgwick and Murchison in the *Transactions of the Geological Society*, noted above.

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Above these there is a succession of beds of shale, impure coal, and volcanic ash, in which I found fish-remains in considerable abundance. This ash resembles that in which my old and esteemed friend Mr. Wünsch discovered the beautifully-preserved plant-remains with which his name is associated. It is scoriaceous, and is commingled with fragments of plants, and remains of fish belonging to several genera. When visiting this spot with the late Sir Charles Lyell I discovered a tooth of *Cladodus*, fragments of other teeth and bones intermixed in great confusion, several portions of large spines, a pectoral bone and scales of *Rhizodopsis*, and those of other species, but the most of them too imperfect for identification. These remains and the matrix in which they are found suggest a sudden outburst of volcanic activity, the ash falling into a shallow lake in which the fish lived, and on the banks of which the plants flourished, the whole being afterwards broken up into splintered fragments and mixed up in the greatest confusion. Their occurrence has not previously been recorded, and I think the section, which is about 50 yards north of the Fallen Rocks, is well worthy of the further attention of palæontologists.

Proceeding round Lagantuin Bay, we pass over the upturned edges of sandstone and ash-beds interstratified. At the northern point these strata are much disturbed by an intrusive igneous dyke, which, at the line of fault, tilts them up at right angles, though near the top they are seen to re-curve slightly. They, however, regain their normal dip a few yards to the north, and, with shales, continue for a considerable way along the shore. We next come to a series of thin bands of limestone, interstratified with shale of a dull, bluish-grey colour, and totally different from any limestone we have met with along the coast, but much resembling the freshwater limestones found in the Blane and Campsie valleys, and known as the Ballagan series. These deposits are overlaid by a series of sandstones and interstratified shales, until we reach a broad dyke of igneous rock, to the north of which the shale is more or less red-coloured; this again is succeeded by the sandstones and interstratified shales.

Further to the north we come to a series of beds which has yielded one of the greatest discoveries ever made along this coast-line, one which has thrown a flood of light upon this horizon of

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strata not to be over-estimated. I refer to the discovery by Mr. Wünsch of trees in volcanic ash, as recorded in the Society's *Transactions.** It revealed to us for the first time that forest trees of Carboniferous age attained large dimensions in that zone, and its publication induced some of our ablest observers to visit and inspect the beds for themselves. Amongst others, the veteran Sir Charles Lyell examined them, and recorded the results of his investigations in his "Students' Manual of Geology," 1871, p. 530. Not only are there the remains of gigantic trees, but there are evidences of seven successive periods during which these trees grew in great luxuriance; at one time a state of repose, at another an outburst of volcanic activity when all organic life was overwhelmed or destroyed. As only the lower parts of the tree-trunks have been preserved with the roots, probably the upper portions were burnt by the ejected volcanic matter, the lower portions of the stems having been previously buried by the showers of ashes.

On visiting this locality with Mr. Wünsch, I suggested the desirability of tracing, if possible, these beds up the hillside, and accordingly ascending by what seemed a line of fault we were rewarded by finding the ash-beds with their enclosed vegetable matter. We also proved the existence of a fault extending across the hillside in a direction slanting upwards—its trend, in other words, being from east to west. Along the line of fault at the western extremity we found several members of the Carboniferous marine deposits exposed at an altitude of about 800 feet above sea-level, and similar to several of the stratified rocks found along the shore-line below. Conspicuous amongst these was the band of limestone in which *Productus latissimus* is preserved in great abundance, and we found limestones containing well-marked Carboniferous types in various places, especially where the surface matter had been washed away by little runnels of water. In following the line of fault further westward, we were led to a corrie of considerable dimensions, into which the rocks converged inwards from all sides. Amongst these was a breccia of a dull reddish-grey colour, the component parts of which differed widely from any breccia I had seen before. I will speak of it farther on.

Proceeding northwards the sandstone is more or less disturbed by igneous rocks until we reach Lagan Bay, on the northern

* *Transactions*, vol. ii., pt. ii., p. 98.

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extremity of which there is a bed of breccia and gritty sandstone of considerable extent, stratified deposits forming a distinct and well-marked boundary line between the marine deposits of the Carboniferous system and the Scottish Lower Carboniferous rocks. Hitherto these beds have yielded few organic remains, though in some instances plants in very imperfect preservation have been found. In all such remains that I have seen the structural characteristics appear as if they had long been exposed to the abrading influences of water and recent shore deposits, such as gritty sand and angular and sub-angular fragments of rock, which form the matrix of the rock now under notice.

The series of beds exposed along the coast-line from Lagan Bay to the Cock of Arran is distinct, and easily separable from the other members of the Carboniferous period; and in the section about to be described there may be seen, with great clearness, the relations of the limestones and superimposed shales, coals, and sandstones, each having its own peculiar witness to its identity embedded in the matrix. In the coals and underlying shales may be found the remains of *Lepidodendron*, *Sigillaria*, *Calamites*, *Stigmaria*, and numerous fragments of small plants, which are often so much broken up and mixed in such endless confusion that they are absolutely useless for either generic or specific identification. In the limestones and calcareous shales may be found the remains of marine organisms, such as corals, annelids, encrinites, polyzoons, brachiopods, lamellibranchs, gasteropods, cephalopods, and fish teeth and scales. Within a few yards of Lagan the lower limestones are well developed, and represent the same stratigraphical position as the Corrie limestones, but the conditions under which the two series of beds were deposited were vastly dissimilar. In the former the abundance of iron floated in amongst the sedimentary matter during its deposition, especially in the lacustrine deposits, would seem to have been all but fatal to the life of the marine fauna. In the latter the limestones and shales appear to have been deposited in water of limited depth, the conditions of the bottom being extremely favourable to the growth of organic life. Some of the shales are literally charged with organic remains. The under beds of limestone and shales are about 30 feet thick, and, where exposed, dip N.-E., resting upon the sandstone. In the lower portion of the limestone are found a few corals, *Producti*, and fish teeth.

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In the interstratified shales we found the following forms, but, as the time we were collecting was very limited, I believe a more extended search would add largely to the list :—

FOSSILS FOUND IN THE INTERSTRATIFIED SHALES AT LAGAN.

ACTINOZOA.

Aulopora sp. ?
Clisiophyllum bipartitum. M'Coy.
Cyathophyllum cylindrica. Scouler.
,, *expansum.* M'Coy.
,, sp. ? (This species was named *C. Wrightii* in Dr. Bryce's list, but, until the type specimen has been cut and properly determined, it must be deleted from all lists.)
Cyclophyllum fungites. D. & T.
Lithostrotion junceum. Fleming.
,, *irregulare.* Phillips.
Lophophyllum eruca. M'Coy.
Stenopora tumida. Phill.
Syringopora reticulata. Goldfuss.
Zaphrentis Enniskilleni. Milne Edwards.
,, *nodulosa.* Phill.
,, *patula.* Michelini.

ECHINODERMATA (ECHINOIDEA).

Archæocidaris Urei. Fleming.
(Other remains of Echinoderms, but too fragmentary for identification.)

ANNELIDA.

Serpulites membranaceus. M'Coy.

CRUSTACEA (TRILOBITA).

Griffithides Eichwaldi. Fischer.

POLYZOA.

Ceriopora interporosa. Phill.
,, *similis.* Phill.
Fenestella carinata. M'Coy.
,, *Morrisii.* M'Coy.
,, *oculata.* M'Coy.
,, *plebeia.* M'Coy.
Glauconome bipinnata. Phill.
,, *pulcherrima.* M'Coy.

BRACHIOPODA.

Athyris ambigua. Sowerby.
,, *Royssii.* Léveille.
Chonetes Laguessiana. De Koninck.
Discina nitida. Phill.

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Lingula squamiformis. Phill.
Orthis resupinata. Martin.
Productus aculeatus. Mart.
,, *costatus.* J. de C. Sowerby.
,, *giganteus.* Mart.
,, *latissimus.* J. de C. Sow.
,, *longispinus.* Sow.
,, *punctatus.* Mart.
,, *scabriculus.* Mart.
,, *semireticulatus.* Mart.
,, ,, var. *Martini.* Sow.
,, *Youngianus.* Davidson.
Retzia radialis. Phill.
Rhynchonella pleurodon. Phill.
Spirifera bisulcatus. Sow.
,, *duplicicosta.* Phill.
,, *lineata.* Mart.
,, *Urei.* Flem.
Streptorhynchus crenistria. Phill.

LAMELLIBRANCHIATA (MONOMYARIA).

Aviculopecten fimbriatus. Phill.
(Several others too fragmentary to be determined.)

LAMELLIBRANCHIATA (DIMYARIA).

Conocardium aliforme. Sow.
Cypricardia rhombea. Phill.
Edmondia rudis. M'Coy.
Leda attenuata. Flem.
Myalina Verneuilii. M'Coy.

GASTEROPODA.

Loxonema scalaroidea. Phill.
Machrocheilus acutus. Sow.
,, *fusiformis.* Sow.
,, *Michotianus.* De Kon
Murchisonia striatula. De Kon.
Naticopsis elliptica. Phill.
,, *variata.* Phill.
Pleurotomaria Yvanii. Lév.

CEPHALOPODA.

Nautilus ingens. Mart.
,, *tuberosus.* M'Coy.
Orthoceros attenuatum. Flem.
,, *ungus.* Phill.

PISCES.

Cochliodus magnus. Agassiz.
Petalodus Hastingsiæ. Owen.

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Following these are beds of calcareous shale, which contain plant-remains, though in a fragmentary condition, and they are succeeded by a series of beds of sandstone and interstratified calcareous shales. Above this is a limestone made up of encrinital remains, which are in so fragmentary a condition that they are difficult to determine, the only fossil to be named with certainty being *Poteriocrinus crassus.* This is succeeded by a broad band of shale, which passes into an impure coal—one of those referred to by Ramsay and Bryce as having been mined. These coals are said to be of inferior quality, but I am not in a position to affirm the statement, as the action of the sea has eroded away the strata for some distance inland, where they have been covered with shore deposits and vegetation, so that now they cannot be seen except at a considerable expenditure of labour and time.

Next there is a series of arenaceous and calcareous beds, overlaid by a limestone readily recognisable by the abundance of a fossil it contains, and which is, therefore, generally known as the *Productus latissimus* limestone throughout the central valley of Scotland. This is overlaid by a series of deposits consisting of calcareous shales and bands of sandstone, and superimposed upon them is a bed of limestone and shale 30 feet thick. The ceaseless action of the waves has eroded away the softer portions of the matrix, leaving in relief the harder organic remains, which, on examination, I found to belong to the upper members of the marine series. Conspicuous amongst others were *Spiriferina octoplicata* and *S. insculpta.* I do not say that these shells are found exclusively in this horizon, but in no series of beds has the latter been found in such great abundance as in the Gare beds, near Carluke, the equivalents of the limestone under notice.

During my short stay I collected from these beds the materials for the following list:—

FOSSILS IN THE 30-FEET LIMESTONE AND SHALE NEAR LAGAN.

ACTINOZOA.

Zaphrentis sp. ?
,, sp. ?

ECHINODERMATA (ECHINOIDEA).

Archæocidaris Urei. Flem.

ECHINODERMATA (CRINOIDEA).

Poteriocrinus crassus. Miller.
Rhodocrinus sp. ?

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BRACHIOPODA.

Athyris ambigua. Sow.
Chonetes Laguessiana. De Kon.
Orthis resupinata. Mart.
Productus costatus. J. de C. Sow.
,, *longispinus.* Sow.
,, *semireticulatus.* Mart.
Spirifera bisulcatus. Sow.
Spiriferina insculpta. Phill.
,, *octoplicata.* Sow.

LAMELLIBRANCHIATA (DIMYARIA).

Leda attenuata. Flem.
Nucula gibbosa. Flem.

GASTEROPODA.

Pleurotomaria monilifera. Phill.
,, *conica.* Phill.

HETEROPODA.

Bellerophon Urei. Flem.
,, sp. ?

Proceeding northwards, we pass over the upturned edges of the superimposed strata, consisting of chocolate-coloured shales, sandstones, and three thin beds of limestone, one of which is an impure hydraulic lime. This series of beds extends for a considerable distance, and the only noteworthy point to which I shall refer is a bed of chocolate-coloured shale, containing numerous round, cream-white spots, varying from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch in diameter. There is usually a dark spot in the centre of each sphere, surrounding, not unfrequently, a small crystal of iron pyrites.

The stratified rocks are now much altered in colour; near Lagan they are greyish-blue, and so continue, more or less, till we reach the *Productus latissimus* limestone, where the change is very marked. Here they are of a dull greyish-red, and this continues till we reach the Cock of Arran, where the sandstone becomes more gritty, and is interstratified with beds of breccia.

This brings us once more to debatable ground. Amongst the different authors who have written on the rocks of this neighbourhood the most prominent are—Sedgwick and Murchison, who, in 1835, classified the rocks of the Cock of Arran as of New Red Sandstone age; Ramsay, who, in 1841, regarded them as belonging to the same formation; Bryce, who, in 1872, placed them as the

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Upper members of the Carboniferous period; Geikie, who, in 1876 (in his New Geological Map), marked these rocks as Upper Old Red Sandstone; and Von Lasaulx, who, in 1878, described them as Upper Old Red Sandstone.

It will thus be apparent that the above-named authors are far from being agreed as to the stratigraphical position of the series of rocks we have now reached; and when observers of such eminence differ so far, it becomes the amateur to be guarded in his deductions. In order that we may trace them in an ascending series from another point—viz., on the crown of the hill, where the breccia extends a considerable distance further inland to the south, and is there seen to overlap the underlying stratified deposits—let us again ascend the hillside to the corrie formerly referred to (p. 22). As there stated, the breccia here is composed of very different materials from that found on the Corriegills shore, consisting of angular and sub-angular pebbles of white quartz, felspathic porphyry, amygdaloidal felstone, fragments of limestone, and chocolate-coloured chloritic shale, all embedded in a matrix of gritty, reddish-grey sandstone. Indeed, some of the particles of quartz in the body of the grit assume a pisolitic aspect, which reminded me of a breccia I saw at St. Bees Head in Northumberland, and of another exposed in the banks of the Ayr Water, near Ballochmyle, in Ayrshire, both being of undoubted Upper Carboniferous age.

Before arriving at any conclusion, let us examine the breccia, in case additional evidence may help us to arrive at a satisfactory solution of the problem. We are now once more upon the line of fault produced by the igneous rocks seen in Lagan Bay, and have reached the corrie, around which the rocks dip inwards and downwards, the sandstones and breccias being intermingled in great confusion. In ascending the hill to the west the breccia is found crowning its top. In a direct line with the fault we come to a series of chasms; one of great depth, the sides of which are festooned with ferns, conspicuous among them the beautiful *Hymenophyllum Wilsoni*, which brought to mind the passage in Tannahill's song—

> "When feathery brackens fringe the rocks,
> And ilka thing looks cheerie, O."

Further northwards we come to the brow of the hill, but find it

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doubtful whether we can get down the northern face of the rugged cliffs which overhang the Cock of Arran. However, we reach the base in safety, not without hairbreadth escapes from treacherous crevasses; but the sight when we reach the shore repays us for all the fatigue and danger. Immense masses of sandstone and breccia, fallen from the cliffs above, skirt the shore-line, lying in great confusion. The hammer shows no trace of organic remains in the rocks—nothing but embedded quartz pebbles, and felstone pebbles of a chocolate-red colour. Passing along the base of the cliffs, we untiringly explore, chipping off a fragment here and breaking off a mass there, in the hope of finding some evidence to clear up the disputed history of these rocks; but all in vain. Now a fine-grained sandstone is overlaid by a more gritty matrix, which passes by almost imperceptible gradations into a brecciated conglomerate.

By this time, having almost given up hope of finding any trace of the remains of organic life, we pass round the point eastwards beyond the Cock of Arran. Ascending a little way up the hillside we observe that the breccia shows a marked difference from that of the Upper Old Red Sandstone on the Corriegills shore. When well up I was startled by Mr. Wünsch shouting, at the pitch of his voice, "Here is evidence of ice-action interstratified with the sandstone!" Hastening downwards, I was delighted to find, at last, the object of our search. Here, indeed, we had a breccia composed of quartz pebbles, chocolate-coloured claystone, amygdaloidal felstone, felspar porphyry of a greenish colour, and fragments of limestone and transported sandstone. In the reddish-coloured limestone were numerous organic remains; a superficial examination of them convinced us that they were all of Carboniferous age. There is thus, then, undoubted evidence that the age of this breccia is no longer problematical, but that it must be grouped with rocks posterior, at least, to the marine deposits of the Carboniferous system, and that it is probably the equivalent of the English Millstone Grit.

After a subsequent careful examination of these organic remains, the following list was drawn up:—

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Fossils in Limestone in the Breccia under the Cock of Arran.

Spongidæ.

? One specimen, unnamed, but determined by Mr. Carter to be a fossil sponge.

Actinozoa.

Amplexus coralloides. Sow.
Aspidophyllum sp. ? Thomson.
Aulophyllum Wünschianum. Thom.
Cyclophyllum fungites. D. & T.
,, sp. ?
Dibunophyllum sp. ? Thom.
Lithostrotion junceum. Flem.
,, *irregulare.* Phill.
,, *Portlocki.* M. Edwards.
**Stenopora tumida.* Phill.
Syringopora reticulata. Goldf.
Undescribed sp. ?
,, sp. ?

Echinodermata (Echinoidea).

**Archæocidaris Urei.* Flem.
**Poteriocrinus crassus.* Miller.

Polyzoa.

Fenestella plebeia. M'Coy.
,, sp. ?
**Glauconome pulcherrima.* M'Coy.
**Rhabdomeson rhombiferum.* Phill.

Brachiopoda.

Athyris ambigua. Sow.
Productus costatus. J. de C. Sow.
,, *latissimus.* ,,
,, *longispinus.* Sow.
,, *semireticulatus.* Mart.

Gasteropoda.

Eulima Phillipsiana. De Kon.
Loxonema Lefebvrei. Lév.
Macrocheilus acutus. Sow.

Heteropoda.

Bellerophon sp. ?

* Subsequent to my visit, the Rev. David Landsborough of Kilmarnock examined this breccia, and sent me several slabs of impure limestone he had found in it. These not only corroborated my own observations, but furnished me with several additions to the list, which I have here marked with an asterisk (*).

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Having thus briefly and imperfectly described the strata along the north-east shore of Arran, I hope that at least enough has been said to induce others to prosecute further investigation on this interesting coast-line. More space might have been devoted to certain points, but even then I could only have approximately described a small section. As it is, in being able to show undoubted evidence for the true identification of the rocks at the Cock of Arran as belonging to the middle zone of the Carboniferous system, or the equivalent of the Millstone Grit of England, and to record the remarkable bone-bed in the volcanic ash north of the Fallen Rocks, I feel that the time I have spent upon the work has not been misapplied.

The section (Plate ii.) illustrating this paper is a copy of one which I prepared at the request of the Executive Committee of the Meeting of the British Association, held in Glasgow in 1876, for the use of its members taking part in an excursion to Arran. A pencil sketch of this diagram submitted to the committee was objected to by Professor John Young, the convener, for the two following reasons:—(1) because it was too detailed; (2) because the rocks on the Corriegills shore and round Brodick Bay were grouped as belonging to the Upper Old Red Sandstone, and therefore debatable. However, at the following meeting, the late Mr. William Keddie and myself were authorised to have it lithographed by Messrs. Maclure & Macdonald for circulation amongst the members of the Association.

I may say that when undertaking to prepare this section I was well aware it could only be imperfect in detail, as in the then existing state of our knowledge of the rocks it was impossible to make it even approximately complete. I hope, however, that so far as it goes it will be found accurate and, therefore, of some use as a guide to the distinctive characters of the Upper Old Red Sandstone rocks and those of the Carboniferous formation in the Island of Arran.

Note.—After this paper was in type I forwarded an early proof copy to the Rev. David Landsborough of Kilmarnock. He replied he was extremely glad to find that I had mentioned Mr. Wünsch's discovery of the junction of the granite and the Old Red Sandstone (page 20), as he was present on the occasion and had examined the junction with great interest.

December, 1896. J. T.

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No. III.—Notes on the Geology of the Island of Eigg. By Henry Taylor. With a Map [Plate III.]

[Read 13th December, 1894.]

Amongst other striking features in the group of islands known as the Inner Hebrides, of which Eigg is a member, are the long level sheets or terraces of igneous rocks, which, rising in places, one above the other, to a height of 2000 to 3000 feet, overlie and preserve the sedimentary rocks from the action of the denuding agents from which they themselves have suffered so much. That these islands are isolated portions of a great series of plateaux which, in comparatively recent geological times, extended along the west coast of Scotland from Skye and Raasay to the north of Ireland, covering an area of probably from 7000 to 8000 square miles, but of which—owing doubtless to long continued denudation—the greater part has now disappeared, is, I think, quite evident. These remaining fragments of the plateaux themselves bear convincing evidence of the great amount of denudation which has taken place in the valleys—sometimes of considerable size—by which they are trenched, and to which other facts to be mentioned in the course of this paper bear additional proof. On this point there is not much, if any, conflict of opinion. As to the history of the volcanic action to which these old terraces or sheets of lava owe their formation, there is not, however, perfect unanimity amongst geological observers, except, perhaps, in so far as that the lavas flowed out on a land-surface and not on a sea-bottom.

Professor Judd, who has devoted himself to the elucidation of this subject for a number of years, maintains that there is conclusive evidence of the eruptions of molten matter having taken place from certain great centres, comparable to Etna and Vesuvius of our own day, of which he locates and describes five—Mull, Skye, Rum, Ardnamurchan, and St. Kilda. He also affirms that there were three distinct periods of volcanic activity, separated by long intervals of time, in which the products of one period were very greatly denuded and altered before the outflows of the succeeding one took place.* These are—

* This volcanic activity began to be manifested in early, and continued with these intervals probably to later, Tertiary times. Prof. Judd has more recently, I believe, modified his views as to the intervals.

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THE ISLAND OF EIGG

(REDUCED FROM THE ORDNANCE SURVEY MAP)

W. & A.K. Johnston Edinburgh & London.

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(1) Eruptions of lavas of intermediate composition, which Professor Judd formerly called "felstones," but latterly after careful microscopic examination, "propylites," a variety of the andesites, accompanied by agglomerates and other fragmentary ejections, the whole surrounding and lying on the flanks of huge masses of granitic rock believed to be the cores of the ancient volcanoes.

(2) Eruptions of augitic or basic lavas, comprising the dolerites and basalts, evidently closely related to the more coarsely crystalline gabbros which penetrate the granite.

(3) Minor eruptions resembling those from the "puys" of Auvergne, the lavas from these being of more or less acid composition.

Sir Archibald Geikie, who has also closely studied this subject, vigorously opposes Professor Judd's views both as to the manner in which the lavas were poured out and as to the sequence of the acid and basic lavas. He asserts that there is no evidence whatever of the lavas having flowed out of great central volcanoes. He believes that the outpouring took place mainly from great fissures in the rocky crust, in a manner similar to that in which the enormous sheets of lava on the Pacific slope, and the Deccan "traps," are thought to have been produced, and he points to the great basaltic dykes underlying the plateaux, or some of them at all events, as probably occupying the fissures from which the lavas welled out. The felstones of Professor Judd he considers to be simply the older basalts much altered or metamorphosed, and the granitic masses or granophyres to have unquestionably disrupted both the gabbros and the plateau-basalt, and so to be younger than them.

The controversy on this part of the subject is evidently not yet closed, but in Eigg there is not so much cause for difference of opinion as in some others of the Western Islands.

The geology of Eigg was described by Jameson, Macculloch, and Hay-Cunningham many years ago, but much has been learned regarding the island since their time. Hugh Miller's charming account of it in his "Cruise of the Betsey" will be familiar to all geologists. More recently it was examined by Sir A. Geikie with most interesting and instructive results, and his description, in the *Quarterly Journal of the Geological Society* for 1871, I have largely made use of in the following remarks:—

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Eigg is about 5 miles long, by 1½ to 3 miles broad, the highest point being scarcely 1300 feet above sea-level, and a hollow, running approximately north-west and south-east, divides it into two nearly equal portions. Hugh Miller not inappropriately compares its outline to that of two wedges placed point to point, with the Scuir—presently to be described—perched on the thick end of the southern one. As already mentioned, it forms a portion of the Tertiary basaltic plateaux. In speaking of the plateau-basalts, I refer to the interbedded or contemporaneous rocks; distinct from these are the subsequent or intrusive sheets which I shall mention later on.

The whole series of rocks has been so tilted as to produce a slight southerly dip, and in consequence of this tilting a portion of the platform of sedimentary strata, upon which the basalts rest, has been exposed from the northern end to the middle of the island; their fossil contents show these strata to be of Jurassic age, belonging probably to the Middle and Lower Oolite. The lowest members are beds of limestone and shale, containing the teeth and bones of reptiles, teeth and scales of fishes, and molluscs. Above these lies a group of massive sandstones with plant and animal remains—these beds being in turn overlaid by another series of fossiliferous limestones and shales, notable amongst them the oyster bed at Laig. The highest member of the series is a soft clay, containing belemnites, ammonites, &c., which is found at the south corner of Laig bay, though, as the bed is almost entirely covered by the boulders of the beach, the former were the only fossils I could get out of it. Some of the sandstones exposed at Laig Bay are strongly calcareous, and contain huge concretions or "pot-stones," from the degradation of which the well-known musical sand has been produced. The igneous rocks of the plateau rest unconformably upon these sandstones, limestones, and shales, as is clearly shown; for the basalts, having a much slighter dip than the stratified beds, are seen to lie across the edges of the latter. Failure to observe this fact partly led to the *basalts* being at one time considered of Jurassic age.

The southern half of the island is composed almost entirely of the plateau-basalts, which rise in more or less horizontal sheets to a height of about 1000 feet, and form a very fine example of the terraced slopes so characteristic of these Tertiary lava-flows. The

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lowest lava-beds at this part correspond to the *topmost* beds in the northern half, consequently it is evident that the *upper* beds of the south end have been removed from the other end by denudation.

The rocks of which the plateau-beds are composed vary from a fine to a very coarse-grained texture. They belong principally to the basalt or dolerite group, and are often markedly amygdaloidal—the minerals commonly filling the cavities being natrolite, analcite, gyrolite, stilbite, pectolite, and chalcedony while others are porphyritic. One mass exposed on the shore, opposite the entrance to the well-known Frank's Cave—the scene of the massacre of Eigg—is of limited extent, and contains, in addition to crystals of labradorite, felspar, and little blebs of black olivine, very large crystals of a greenish plagioclase felspar, a variety intermediate between anorthite and labradorite, known as bytownite. It has been found by Dr. Forster-Heddle in the gabbro at Hart o' Corry in Skye, but has not, so far as I know, been previously reported from Eigg. Another interesting rock is to be seen over- and under-lying a bed of rich analcite-bearing amygdaloid, adjoining the Scuir, near Loch a Bhealaich. It is a heavy basic rock, and outwardly resembles picrite of which there are several examples in the adjacent island of Rum. A somewhat similar mass is to be seen underneath the eastern end of the Scuir.

A notable feature of the plateau-basalts all over the island, but best seen, perhaps, along the eastern cliff of Beinn Bhuidh, is columnar structure, of which there are many beautiful examples, the columns varying from a few inches across to several feet. Sometimes they are vertical, at other times nearly horizontal, and often they occupy many curious intermediate positions. Intercalated bands or layers of a red clayey material—often very hard—are among the basalts, and vary in thickness from a mere parting common to several inches or even feet. They are considered to be the baked and hardened representatives of the soil which formed on the surface of the lava-beds in the interval between successive outflows. On the surface of some of the sheets exposed by the action of the sea at the south end of the island a very marked ropy-like structure is to be seen.

Interbedded with the basalts of the north end, and readily to be distinguished from them by its colour, is a thick sheet of pale

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grey rock of more acid composition than the basalts, and which has been classed with the andesites, one of the groups of rocks of intermediate composition. This bed is well exposed along the eastern cliff of Beinn Bhuidh, and it emerges from underneath the overlying rocks about the middle of the island, consequently occupying a portion of the central hollow. Professor Judd mentions that he found other similar beds in the island. These rocks are of interest as showing that during the period of eruption of the basic lavas there were occasional outflows of more acid material.

There is a scarcity in the island of fragmentary volcanic rocks such as breccias, agglomerates, and tuffs, a fact referred to by Sir A. Geikie in one of his arguments against the theory explaining the outflow of the plateau-rocks through volcanic craters.

Of later age than the interbedded or contemporaneous lavas of which we have been speaking, but belonging, doubtless, to the same period of volcanic activity, are the numerous *intrusive* sheets or sills of similar rock which pierce alike the sedimentary strata and the overlying volcanic masses, and which are found most abundantly near the base of the interbedded series. The sandstones and shales at the north end of the island are greatly split up by these intrusive rocks—a marked alteration of the sandstone along the line of contact being observable, one of the principal tests by which we recognise an intrusive sheet. The material composing these sheets is on the whole finer-grained than that of the plateau-rocks, and the edges are more finely crystalline than the inner portions. Both series have, doubtless, been derived from the same fluid magma—the intrusive sheets being such simply because, owing to the great and increasing weight of the overlying masses, the liquid lava could not force itself to the surface so easily as it could make its way along the weaker planes of the various strata.

Numerous basalt-dykes run throughout the island, approximately in the same direction, *i.e.*, north-west and south-east. In many cases they are clearly younger than either the plateau-basalts or the intrusive sheets, as they often cut through both from top to bottom. They can be observed traversing the cliffs at various places, being beautifully displayed at Laig Bay, where they run out to sea in long straight lines. Frequently the sandstones through which they cut have, for a short distance from the line

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of contact, been so baked and hardened as to resist weathering better than the dykes themselves, with the result that deep vertical gulleys have been formed; while occasionally, and generally where they are more or less closely crystalline, the dykes stand up prominently above the stratified rock. As a rule the dykes are more finely crystalline than the intrusive sheets, the contact edges often showing black glossy tachylyte.

While speaking of dykes, I might say that, though the evidence which Professor Judd has brought forward to prove the former existence of great volcanoes in the Western Isles seems convincing, it does not appear to me unreasonable to suppose that, if the hundreds or thousands of fissures which exist in this area reached the surface at the time they were injected with the molten material now consolidated in them, enormous quantities of it may have been poured out thus.

The next series to be described contrasts strongly with those previously mentioned, the rocks belonging exclusively to the acid group, and being of later date than the basalts which they disrupt. Included in it are three intrusive masses now called by Sir Archibald Geikie "granophyric porphyry," a rock approaching the granophyres and granites found in the other islands. The largest exposed mass, which is at the north end of the island, is partly columnar, and is traversed by basalt veins, showing that all the latter are not of the same age. Another mass is to be seen near Laig road in a line with the farm, and with it occurs a vein of pitchstone, but, although there is apparently some relationship between the two, what it is is not clear. A third mass rises through the plateau-rocks below the Scuir near Grulian.

At Rudh an Tangairt a very regular vein, or dyke, of material very similar in outward appearance to some of the masses just mentioned is seen traversing the dolerites of the plateau for a short distance. Where it stops a pitchstone takes its place, the junction being somewhat irregular. The portion of the fissure occupied by the former rock contrasts very strikingly with that occupied by the pitchstone, the one being very regular and the other quite the reverse. Another vein of pitchstone ascends the cliff a few feet west of the one already noted. These veins look at several places as if they had been fractured and then slightly displaced; and where this seems to have been the case, the partially

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truncated ends have assumed a platey and somewhat friable structure. This structure is also seen in pitchstone occupying a cavity above one of the veins, of which it is quite clearly a detached part. Another pitchstone vein, very similar to the others, occurs near the harbour.

We now come to one of the most interesting rocks—the porphyritic pitchstone—of which that striking and scientifically-famous landmark, the Scuir of Eigg, is mainly composed. This peculiar mass extends along the highest part of the plateau at the south end of the island in a nearly east and west direction for about 2½ miles, and at its eastern extremity rises sheer from the plateau to a height of nearly 400 feet, presenting the appearance of a huge wall or dyke, which, indeed, some of the older geologists believed it to be. Professor Judd classes this pitchstone porphyry with the glassy form of the andesites. It contains large porphyritic crystals of sanidine, and also of plagioclase with small crystals of augite and magnetite. It corresponds in petrographical characters, according to Judd, with the rocks of the Tertiary dykes traversing the south of Scotland and the north of England. It is wholly columnar, and the different sets or beds of columns, arranged sometimes vertically, sometimes horizontally, and in many intermediate and curious ways, show, without doubt, that there were several flows. Associated with it are several bands of somewhat similar but much paler-coloured rock, which has been named felstone-porphyry, and is probably an example of the pitchstone devitrified. It sometimes contains much magnetite.

The rocks of the Scuir are the latest examples of volcanic material in this area. They belong to Professor Judd's third period of volcanic activity, and are believed by him to have flowed out from a minor vent or "puy" similar to those of Auvergne, probably situated on the flanks of the great volcano of Rum. Evidence, however, to which I shall allude immediately, seems to prove that the position of this particular vent must have been elsewhere than in the island of Rum.

Between the last outflow of the basic lavas of the plateau and the first one of the acid pitchstone-porphyry of the Scuir a vast interval of time must have elapsed, for the latter occupies the site of an old river valley hollowed out of the plateau. This is shown

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by the fact that, in several places underneath the brecciated base of the pitchstone, gravelly material consisting largely of water-worn pieces of basalt, sandstone, quartzite, and clay slate, together with fragments of coniferous wood (*Pinites Eiggensis*) and larger masses of drifted material, is to be found.

There must therefore have been sufficient time between the out-flows of the different classes of lava for the erosion of this old river valley to a considerable depth. The existence of the river-gravel under the Scuir, first mentioned by Sir A. Geikie, is of great interest, not only in itself, but also from the bearing which it has on the time since the last of the lavas preserved to us flowed over these islands, a period geologically quite recent. The interval between then and now must be enormous, for when the pitchstone flowed into the old river valley the latter would be bounded on both sides by rising ground, as all valleys are, but this state of things has been entirely changed. The once higher ground on the south side of the old valley has been denuded away down to the base of the Scuir, and from there, owing to the same cause, it now descends to the sea with a comparatively steep slope; on the north side the ground now gently slopes towards the central hollow. The Scuir itself remains only because of the much greater resistance of its component material to the weathering influences. It should also be mentioned that the Scuir is situated on the side of sloping ground, not exactly on a flat summit, and consequently at one place about 100 feet *higher* from the ground on the southern side than on the northern. This fact itself proves that there must have been much higher ground bounding it when the lava flowed out, which otherwise would not have remained in its present position.

As to the direction in which this old river flowed, the fact that the base of the Scuir is much higher at the eastern than at the western end, and further, that a similar rock has since been found at a much lower elevation in the small island of Hysgeir, about 20 miles to the west of Eigg, leaves no doubt, I think, that it, as well as the lava which subsequently filled up the valley, flowed from the east, and not from the west. This is confirmed by the additional fact that pebbles of various rocks, which are found *in situ* only to the north and east, are present in the

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gravel under the Scuir. Here, then, is a further proof of the great denudation which has taken place, for the land, which once united what is now the island of Eigg to that from which the pebbles and blocks found in the bed of the old river have been derived, has been entirely removed. In short, to use Sir A. Geikie's own words *—"What were once hills have disappeared, and what used to be a valley is now the crest of a lofty hill. The pitchstone which, when it rolled down that ancient water-course, sought the lowest level it could find, rises to-day into one of the most conspicuous landmarks in the West of Scotland."

* "The Scenery of Scotland viewed in connection with its Physical Geology." [Sir] Archibald Geikie, LL.D., F.R.S., 2nd ed., 1887, p. 153.

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No. IV.—On *Cladodus Neilsoni* (Traquair), from the Carboniferous Limestone of East Kilbride. By R. H. Traquair, M.D., LL.D., F.R.S., Keeper of the Natural History Collections in the Museum of Science and Art, Edinburgh. With a Plate [No. IV.], by the Author.

[Read 10th May, 1888; revised and given in for publication, March, 1897.]

In 1888 I published a brief account of this remarkable specimen, which has been since that time frequently referred to by writers on palæozoic Selachii. I regret that it is only now, after an interval of nearly nine years, that I send to the Secretary of the Society a detailed description, accompanied by drawings; but perhaps there is, after all, a counterbalancing advantage in having meanwhile been able to compare it with the descriptions and figures of other ancient Cladodont sharks given by American writers, namely, Newberry, Claypole, Bashford Dean, and Cope.

But as the main object of the present paper is to lay before ichthyologists the facts which are shown in this unique specimen, I shall for the present avoid as much as possible the discussion of those theoretical points which may be suggested by the structures therein displayed.

Description.—The specimen represented in Plate iv., fig. 1, as one half natural size, is in the collection of Mr. James Neilson of Glasgow, who obtained it from the late Mr. Andrew Patton of East Kilbride, by whom it was recovered from the quarry there. As the pieces of which it is composed came up separately from the workings, Mr. Patton did not, I understand, feel quite sure that they all belonged to the same specimen. They were, however, fitted together by Mr. Neilson, and after a most careful scrutiny of the whole, I came to the conclusion that the fragments did belong to the same specimen, and that they were rightly arranged.

We have here the greater part of the head, the branchial apparatus, the shoulder girdle, and the two pectoral fins—the parts exhibited covering a space 20 inches in length.

The head, crushed vertically, is in this figure seen from above. On the left side the cranium (*cr.*) is imperfect—a large portion, both laterally and anteriorly, being cut off by a line passing from a point to the right of the centre of the front of the rostrum obliquely backwards and outwards. On the right side it is easy

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to distinguish the margin of the orbit (*o.*) with its preorbital process in front, and bounded posteriorly by a strong, pointed, nearly triangular postorbital projection, behind which the lateral cranial margin proceeds nearly straight backwards to join the transversely directed occipital one, the angle being however cut off.

As here exhibited the cranium is 5½ inches in length, and one cannot fail to be struck with the resemblance which it bears in its contour to that of the Notidanidæ (*Notidanus*, *Chlamydoselache*).

On the side of the cranium, and behind the postorbital process, is the attachment of a strong, straight portion of cartilage, which passes backwards and slightly outwards for a distance of 5 inches. The only interpretation which can be placed on this cartilage is that it represents the *hyomandibular* element.

Behind the cranium, and extending back for a distance of 6 inches, and occupying a breadth of 4, is a confused mass (*br.*), consisting evidently of rod-like cartilages, all broken and crushed together. We see in this mass the remains of the branchial apparatus; and though there is no possibility of identifying individual branchial arches, the whole ends behind in a free pointed process (*c.*), which is plainly the posterior extremity of the last basibranchial piece, and which we find forming a similarly shaped and similarly placed pointed process in a large number of recent Selachii.

The anterior piece of the fossil can now be lifted up and turned over, as it is represented in fig. 2, in which we have a view of a large portion of the *under* surface of the head.

We are first struck by the two rami of the lower jaw (*mn*), which converge anteriorly to meet at a very acute angle; owing to vertical crushing the substance of these rami appears folded longitudinally. External to the margin of the lower jaw on each side, the whole space is covered with teeth, but these teeth are all in disorder, forming a confused mass in which nothing of their original arrangement can be seen. There can be no doubt that the cartilage upon which these teeth rest is the palato-quadrate, though the teeth themselves appertain to both jaws.

So far as can be seen in the specimen, all the teeth are similar in size and shape. Each consists of a base surmounted by pointed and striated cusps. The base equals (in the specimen figured in

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Plate iv., fig. 4) $\frac{3}{8}$ inch in transverse and $\frac{1}{8}$ inch in antero-posterior diameter; it is flat below, oval in outline, but having the anterior contour flatter than the posterior, and it is also to be noted that at the anterior margin there is a small flattened button-like projection in the middle line.

From the upper surface of the base rise the pointed cusps, but it must be noted that *the front of the base forms a sharp margin* (fig. 3) *marked off from the cusps at their origin*, and by this feature the present specimen of *Cladodus* is distinguished from all others with which I am acquainted.

The cusps are ordinarily five in number—one large median, with two smaller lateral ones on each side. The median cusp is conical and pointed, about as high as the transverse diameter of the base is long; it is slightly inflated below and very gently recurved, oval in transverse section, becoming two-edged upwards. The surface is covered with fine sub-parallel, nearly straight, vertical striæ, which increase towards the base by intercalation.

On each side there are two smaller cusps, of which the outer and larger is slightly divergent in its direction, while the inner and smaller has its axis more parallel with that of the central one. These two smaller cusps are conformed and striated like the central one.

If we now return to that portion of the fossil which lies behind the head and the remains of the branchial apparatus, we are at once struck by the presence of two largely-developed *pectoral fins.*

That of the right side is attached to a scapulo-coracoid cartilage (*s.c.*), whose postero-superior extremity is clearly exhibited, while its antero-inferior one is apparently concealed by the crushed mass of branchial cartilage. It is expanded anteriorly, and gently curved—the anterior margin being regularly concave, but the posterior one shows a bluntly angular projection to which the fin is attached.

The elements of this fin are seen to fall into two sets, proximal and distal, separated by a longitudinal line of joints. These correspond respectively with the "basals" and "radials" of the ordinary shark pectoral.

The proximal or basal set consists first of some eight or nine staff-shaped pieces (*pt.*), each about $\frac{3}{4}$ inch in length, placed close together, and having their proximal extremities attached to the

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above-mentioned projection of the posterior margin of the shoulder-girdle. These are immediately followed posteriorly by a flat oblong trapezoidal piece (*mt.*) $1\frac{3}{4}$ inch in length, and broader in front than behind. Its anterior portion shows some slight appearance of having been formed by the fusion of staff-like bars similar to those in front. The rest of the surface is flat, while its narrow posterior margin articulates with the first of a series of nine flattened rectangular pieces, forming a posteriorly-directed narrow jointed stem which attains a length of five and a half inches.

The distal elements consist of slender cylindrical rays (*r.*) articulated to the shorter staff-like proximal pieces (*pt.*), and to the oblong piece behind these (*mt.*). Closely placed, they rapidly increase in length in front and fall off more gradually behind, the longest being cut off by the edge of the stone. But it is also to be noticed that behind these closely set rays attached to the pieces marked *pt.* and *mt.*, there are three which are shorter, more slender, and more distantly placed. One of these arises from the junction between the oblong plate (*mt.*) and the first small rectangular joint of the longitudinal chain; the second from the junction between the first and second of these pieces; the third from the middle of the second piece of that chain. On the inner or post-axial side of the chain no rays whatever are seen.

The fin of the left side is much less perfectly preserved. Only a small portion of the scapulo-coracoid cartilage is seen, but the rest of the elements are clearly indicated, though no small rays appear on the outer aspect of the chain. The two chains, right and left, cross each other near the hinder edge of the stone, but that this is obviously a *post mortem* distortion it is hardly necessary to remark.

Observations.—I hardly think that, so far as the configuration of the teeth is concerned, anyone will deny to the present specimen a position in the genus *Cladodus* of Agassiz, though it differs markedly from the type species *C. mirabilis* (Ag.) in the front of the base of the tooth, which shows, below the origin of the median cusp, a prominent rim instead of a shallow excavation. And although there can be no doubt that the Cladodont shape of tooth was also present in form generically distinct from the typical *Cladodus*, it will certainly be convenient to retain the

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East Kilbride specimen, provisionally at least, in the genus in question.

As to species, it is certainly not referable to any of those which are ordinarily known, the only form resembling it being *Cladodus Hibberti* of Agassiz, from Burdiehouse—at least judging from the figure given by Agassiz in the "Poissons Fossiles." But neither that figure nor the description in the text is adequate to determine the species in the absence of the type specimen, which seems unfortunately to be lost. Feeling therefore under the necessity of devising a new specific name for the above-described fish, I have pleasure in adopting for it the name of my friend Mr. Neilson, to whose kindness I am indebted for the loan of the specimen and permission to publish it.

The next point to be noticed is the great resemblance which the skull of *C. Neilsoni* bears to the skull in the living Notidanidæ, and especially to that of *Chlamydoselache*, Garman. It will be remembered that Garman, in his description of that remarkable genus, specially insisted on its relation to the extinct Cladodonts, on account of the configuration of the teeth of which those at least which are situated towards the angle of the mouth are very Cladodont in appearance. But the skeleton of the pectoral fin has in *Chlamydoselache*, as in *Notidanus*, already assumed the structure of the ordinary shark pectoral, its basal elements showing the three characteristic pieces named by Gegenbaur propterygium, mesopterygium, and metapterygium; and though the latter has more than one segment, it does not run back in the form of a long many-jointed chain, as in the fish now before us. It is, however, of great interest to see that there is a bond between *Cladodus* and *Chlamydoselache*, though the alliance is perhaps not quite so close as Mr. Garman supposed.

And if this species *Neilsoni* be rightly referred by me to the genus *Cladodus* of Agassiz, then Bashford Dean is also right in separating, under the new generic name of *Cladoselache*, those remarkable fishes with Cladodont teeth, flap-like paired fins, and sclerotic ring, from the Upper Devonian of Ohio, which had been referred to *Cladodus* by the late Professor Newberry. For so far as Dr. Dean's researches go, the basal arrangement in the paired fins of *Cladoselache* are of a simple character, and there is no trace of the long-jointed stem which is so prominent a feature in the pectoral of *C. Neilsoni*.

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And what is, in point of fact, the real significance of that remarkable arrangement of cartilages exhibited in the pectoral fin of *Cladodus Neilsoni?*—that is the question which gives the specimen its chief interest.

The skeleton of the pectoral fin of the recent sharks, with its three basal cartilages, *propterygium*, *mesopterygium*, and *metapterygium*, which intervene between the shoulder girdle and the radials, is maintained by Gegenbaur to have been probably derived from an arrangement like that in the recent *Ceratodus*, where we have a median segmental stem, fringed with radials on each side, postaxial as well as preaxial. To this type of paired fin-structure which occurs not only in both pectoral and ventral limbs in Dipnoi, *e.g.*, in the recent *Ceratodus* and the fossil *Dipterus*, *Phaneropleuron*, &c., but also in the pectoral of the fossil Crossopterygian *Holoptychius* and of the fossil Selachian *Pleuracanthus*, Gegenbaur applies the term *Archypterygium* as embodying the idea of its primitive character in relation to the paired fin-structure seen in more modern sharks and other fishes. And the mode in which he supposes the Archypterygium to have evolved into the usual Selachian arrangement is briefly as follows:—The median stem simplified, shortened up, and losing all its radials on the postaxial side, except in some cases, a few near the tip, becomes the metapterygium, while the mesopterygium and propterygium are formed by the fusion into two pieces of the basal joints of a number of preaxial radials which have reached and become attached to the shoulder girdle in front of the metapterygium.

Now, the specimen of *Cladodus Neilsoni* before us gives what seems to be a remarkable corroboration of the truth of the general correspondence of the parts. The oblong trapezoidal piece (marked *mt.* in Plate iv., fig. 1), with its succeeding chain or stem of narrow joints, is unquestionably the metapterygium, while the mesopterygium and propterygium are equally clearly represented by the still separate staff-shaped cartilages (*pt.*) in front, which, according to Gegenbaur's view, may be the basal joints of the more anteriorly-situated preaxial radials, to whose extremities they are articulated distally, while proximally they have reached the shoulder girdle. As there are no radials on the postaxial side of the metapterygial stem, I stated in my first description of the

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specimen that the arrangement was "capable of bearing the interpretation that we have here a veritable uniserial archypterygium intermediate between the truly biserial one of *Xenacanthus* (*Pleuracanthus*) and the pectoral fin of ordinary sharks." Furthermore, I added that "if this interpretation is correct, then along with *Xenacanthus* this specimen is a witness against the lateral fold theory of the paired fins at present so popular with anatomists and embryologists."

A fragment of a Cladodont fish from the Coal Measures near Galesburg, Ohio, has, however, been recently described by Professor Cope under the name of *Symmorium reniforme*, in which, while the pectoral fin bears some resemblance to that of my *Cladodus Neilsoni*, the metapterygium is not divided into transverse segments. Remarking on this form, Professor Cope observes that "the fin-structure discovered by Traquair, contrary to his supposition, supports the ptychopterygium theory, and the modern fin is derived not from the archipterygium but from the ptychopterygium."

To enter here into a discussion of the archipterygium and lateral fold theories of the paired limbs would carry us far beyond the scope of the present paper, which is simply to give an accurate figure and description of the specimen of *Cladodus Neilsoni* from East Kilbride. It will suffice for the present if I point out the way in which the supporters of the lateral fold theory, in the form advocated by Cope and Bashford Dean, will naturally explain the pectoral fin-structure which is exhibited in that specimen.

According to that theory the pectoral and ventral members represent portions now isolated of an original hypothetical lateral fin-fold, from which they have been evolved while the intermediate portion of the fold has disappeared. The earliest stage in the development of skeletal structures will then be seen in the paired fins of *Cladoselache*, figured and described by Newberry, Bashford Dean, and Smith Woodward, in which these organs appear to form fold-like rounded-triangular projections from the side of the body, supported by rod-like "radial" cartilages jointed to shorter "basals" placed in the body-wall. This is the "*Ptychopterygium*" of Cope.

From these basal cartilages the propterygium, mesopterygium, and metapterygium of ordinary sharks will be evolved by a process

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of fusion, the metapterygium having also a tendency to rotate outwards and so become *external* to the body-wall.

What then, according to this scheme, is the central-jointed axis of the *Pleuracanthus* or *Ceratodus* fin? It will still remain the equivalent of the metapterygium, but the process of evolution will have proceeded precisely in the opposite direction to that conceived of in the theory of Gegenbaur. The metapterygium will have to be looked upon not as formed from the fusion of the joints of an original central axis, but from the fusion of basals whose original position was in the body-wall; not as having originally had radials on both sides (biserial), but as having had them originally only on the preaxial side (uniserial); not as having been originally a projection from the outline of the body, but to have been originally *in* the body-wall, and then, *turning outwards*, to have *subsequently* acquired radials also on the postaxial side, so as to form the central axis of such a fin as is seen in *Pleuracanthus* and in the Dipnoi.

Turning now to our *Cladodus* from East Kilbride, it is easy to see how the supporters of this view will find in it a corroboration of their ideas. A line of articulations separates the slender cartilages (*r.*) (Plate iv., fig. 1), both from the staff-like elements (*pt.*) (= propterygium and mesopterygium) and from the oblong piece (*mpt.*) which, with its appended chain of little rectangular pieces, represents the metapterygium. The staff-like bodies (*pt.*) will then not be, as Gegenbaur's theory requires, the proximal joints of archypterygeal radials which have reached the shoulder-girdle, but *basals* which still remain ununited, while in the first oblong piece of the metapterygium (*mpt.*) they are fused—the succeeding rectangular segments of the chain being also formed, each from a certain number of united basals. Thus, instead of this *Cladodus* fin being a transition from the *Pleuracanthus* form to that of the ordinary shark, it will, from this point of view, be a transition from the "ptychopterygium" of *Cladoselache* to the *Pleuracanth* and Dipnoian limb.

It will also, however, have to be noted that, while Cope and Bashford Dean would derive the tri-basal pectoral of ordinary sharks direct from the ptychopterygium, Fritsch and Smith Woodward would look upon it as being again in its turn derived from the *Ceratodus*-like fin of *Pleuracanthus*.

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As I have said previously, it would be out of place for me in the present paper to enter into a discussion of the enormous subject of the evolution of the skeleton of the paired fins in fishes. More especially as practically a new aspect has been given to the matter by Dollo in his recent valuable paper on the "Phylogeny of the Dipnoi"—his views demanding most careful thought and study before we can venture either to accept or reject them. It is, however, plain that if Dollo's theory as to the origin of the Dipnoi from the Crossopterygian "ganoids" is correct, then the "archypterygium" of the Selachian *Pleuracanthus* must have had a distinct origin from those of the Dipnoan *Dipterus* and *Ceratodus.*

Literature.—The literature of the fin-question is enormous. It is, however, only necessary here to note such works as more especially bear upon the subject of the above paper :—

1. Cope, E. D.—"New and little-known Palæozoic and Mesozoic Fishes." *Journ. Acad. Nat. Sci., Philad.*, vol. ix., 1894, pp. 427-431.
2. Dean, Bashford.—"Contributions to the Morphology of *Cladoselache.*" *Journ. Morphol.*, vol. ix., 1894, pp. 87-114.
3. Dean, Bashford.—"A New Cladodont from the Ohio Waverley." *Trans. New York Acad. Sci.*, vol. xiii., 1894, pp. 115-119.
4. Dean, Bashford.—"The Fin-fold Origin of the Paired Limbs, in the light of the Ptychopteryga of Palæozoic Sharks." *Anatomischer Anzeiger*, vol. xi., 1896, pp. 674-679.
5. Fritsch, A.—"Fauna der Gaskohle, &c., der Permformation Böhmens," vol. iii., pt. 2, 1893.
6. Gegenbaur, C.—"Das Flossenskelet der Crossopterygier und das Archipterygium der Fische." *Morphol. Jahrb.*, vol. xxii., 1894, pp. 119-160.
7. Traquair, R. H.—"Notes on Carboniferous Selachii." *Geol. Mag.* (3), vol. v., 1888, p. 76.
8. Woodward, A. S.—"Catalogue of Fossil Fishes in the British Museum," pt. ii., 1891.
9. Woodward, A. S.—"The Evolution of Fins." *Nat. Sci.*, vol. i., 1892, pp. 28-35.
10. Woodward, A. S.—"The Problem of the Primæval Sharks." *Nat. Sci.*, vol. vi., 1895, pp. 38-43.
11. Dollo, L.—"Sur la Phylogenie des Dipneustes." *Bull. Soc. Belge, Geol., Palæont., Hydrol.*, t. ix., 1896, pp. 79-128.

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Explanation of Plate IV.

Fig. 1.—Head and pectoral fins of *Cladodus Neilsoni*, Traq., Lower Carboniferous, East Kilbride, in the collection of Mr. James Neilson, Glasgow. One-half natural size; *o.*, orbit; *h.m*, hyomandibular; *br.*, branchial cartilages; *c.*, pointed posterior extremity of the last median basibranchial piece; *s.c.*, scapulo-coracoid cartilage; *r*, radials; *pt.*, cartilages equivalent to the propterygium and mesopterygium; *m t.*, cartilage equivalent to the metapterygium of ordinary sharks, and to the median-jointed stem in the pectoral of *Pleuracanthus*.

Fig. 2.—Head of the same specimen turned round, and seen from the under surface. *m n*, rami of mandible.

Fig. 3.—Tooth magnified.

Fig. 4.—Base of tooth seen from below, and magnified.

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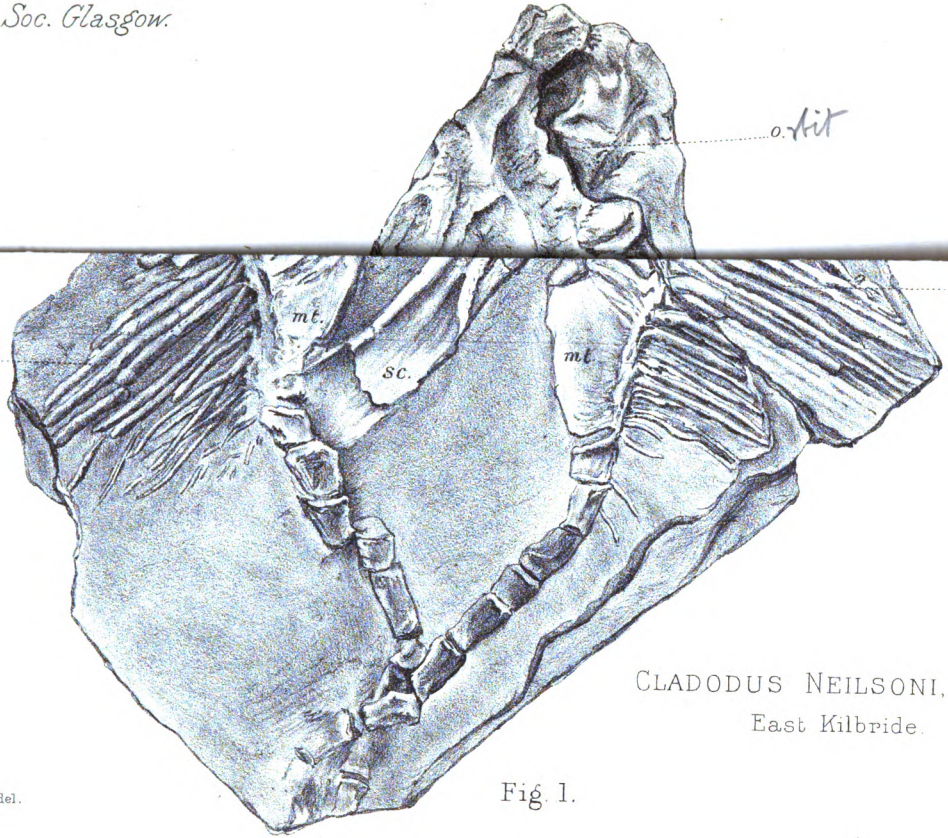

CLADODUS NEILSONI, *Traquair.*
East Kilbride.

Fig. 1.

R.H. Traquair, ad. nat. del.

McFarlane & Erskine, Lith^ts Edin^r

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No. V.—On the Genus *Phillipsastræa*. By James Thomson, F.G.S., Hon. Member; Cor. Member Royal Society, Liége; Hon. Member Royal Ducal Society, Jena. With Two Plates [Nos. V. and VI.].

In a presidential address to the Biological Section of the Philosophical Society of Glasgow "On the Development and Generic Relations of the Corals of the Carboniferous System,"* I briefly referred to *Phillipsastræa* of d'Orbigny, 1849, along with other genera. Since then Dr. Schäfer † has criticised the deductions of Messrs. Milne Edwards and J. Haime and others as to the relationships of *Phillipsastræa* and *Smithia*, E. and H. He refers to the conical boss and other structural details frequently met with in the calices of the former genus, and to my diagnosis of the structural characters found in the Scottish forms, and more particularly to the columellarian boss so common in the calices of the corallites of *Phillipsastræa*. When Dr. Schäfer's paper appeared I was engaged upon the examination of the genus *Campophyllum*, the result of which appeared in the *Transactions of the Royal Irish Academy*,‡ but my subsequent long illness has prevented me from hitherto reviewing the structural characters of the varied Scottish forms of *Phillipsastræa*. Further, in consequence of the emphasis placed by Dr. Schäfer on the presence or absence of a columella, I was desirous of visiting the only locality in Scotland where this interesting group has yet been found, in order to make the evidence as clear as possible, and I am pleased to say the specimens procured have substantiated my former observations, and have revealed new structural details. One specimen shows under the microscope the granular sclerodermic tissue of the septa to be minutely crenulate; another well-preserved specimen shows a series of minute granules along the lateral margin of the septa; another has much coarser granulations; and in all there is a series of minute pores between the granulations—all points of considerable interest. Should Dr. Schäfer wish, I shall be delighted to show him the whole series upon

* *Proceedings of the Philosophical Society of Glasgow*, 1883, p. 99.

† "On Phillipsastræa, d'Orb., with especial Reference to *P. radiata*, S. Woodward, sp., and *P. tuberosa*, M'Coy, sp. By Rudolph Schäfer, Ph.D." *Geological Magazine*, Sept., 1889, p. 398.

‡ Read 13th April, 1891; published 1893.

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which I have founded my deductions. Some specimens of the series vary much from *Phillipsastræa radiata*, whilst others so nearly merge into the type that I am not surprised at the varied opinions of palæontologists both in regard to the structural details and the value attached to them. While some consider *Phillipsastræa* as distinct and separable from *Smithia*, others regard these genera as merely varietal.

Before noting these different opinions it may be well to state the generic characters of *Phillipsastræa* as defined in my Address above-mentioned, and to include the recently discovered facts.

GENUS—*Phillipsastræa*, d'Orbigny.

Generic characters: — Corallum compound and formed of vertical corallites in astræiform masses of variable thickness; development by fissiparity; the corallites radiate with uniform divergence from the parent, which seems to have been attached to some foreign body. Epitheca thin, and developed along the underside of the corallum; there are irregular broad annulations of growth. The septa are bilamellar, more or less confluent, and radiate outward in irregular distances. Mural pores are present, exposed along their lateral margins, and there are comparatively large pores at the junction of the interseptal dissepiments in the floor of the interseptal spaces. The primary septa extend inwards, project, and descend to the base of the calicular fossa as keeled ridges. The secondary septa do not extend to the margin of the calicular fossa, the centre of which is variable. In some corallites it is flat, in others more or less convex; in another the lamellæ extend inwards and upwards, and the interlamellar spaces are closed in by convex interlamellar dissepiments, and form the conical columellarian boss in the centre of the fossa. In yet another form the lamellæ are more or less fasciculate, and are slightly elevated in the centre of the columellarian fossa.

From the polymorphic structural characters of this interesting series found in one locality, it will be at once apparent, as formerly stated, how natural it is that palæontologists should differ, both in the specific distinctions they adopt in regard to them, and in the value they attach to them. In nearly all the slabs now lying before me, there are corallites which, if sectioned individually, would show how naturally such divergent opinions might arise

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regarding them, induced largely by the method adopted in the preparation of the sections. As the corallites are irregular in their arrangement, in one longitudinal section the centre may be exposed, revealing the columellarian line; in others the section may be shown a little off the centre, no columellarian line being visible; and in some in which the up-curved tabulæ are only periodically exposed, not along the central plane of the corallite, the aspect of the structural details is very different from what it would be if the centre of the corallite were shown. In sections now before me the upper portion shows the columellarian line, while in the lower the tabulæ are irregular and the columella is not seen, as the corallites are more or less curved, and the section does not expose the central area, but shows the curved tabulæ a little off it. This, well shown in one of Dr. Schäfer's illustrations,* is a physiological point requiring more consideration before we can definitely assert that the columella is not present. Indeed, in several genera of Carboniferous corals similar conditions exist, and many of the divergent opinions expressed by authors can only be accounted for in some such way. Before proceeding to examine these differences, I shall enumerate the structural details upon which some of the authors rest their definitions.

In 1849 d'Orbigny established the genus *Phillipsastræa*, of which he gave the following diagnosis :—

"*Phillipsastræa.*† Ce sont des *Siderastrea*, dont la columelle, au "lieu d'être styliform saillante, est large et divisée en cloisons "rayonnantes, comme chez les *Columnastræa.*"‡

"Corallum composite, resembling *Strombodes*, but differing from "them by the septa or costal radii of the neighbouring corallites "being confluent, and consequently the calices not being definitely "circumscribed. No exterior walls; the interior mural investment "well characterised. The centre of the tabulæ presenting a "columellarian tubercle. Typ. Sp."§

M. Edwards, in his "Histoire des Coralliaires,"‖ thus describes the genus—"composite, coral astræiform, multiplying by sub-

* *Geol. Mag.*, Sept., 1889, plate xii., fig. 5.

† A. d'Orbigny, Prodr. de Paleont., &c., vol. i., p. 107, Paris, 1849.

‡ In Edwards and Haime's "British Fossil Corals," Introduction, p. lxx. d'Orbigny, Note sur des Polypiers fossiles, p. 2, 1849.

§ *Phillipsastræa Hennahi*, d'Orbigny, *loc. cit.* *Astrea Hennahi*, Lonsdale, *Geol. Trans.*, 2nd series, vol. v., tab. lviii., fig. 3. ‖ Vol. iii., p. 435.

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"marginal gemmation, corallites closely connected, well-developed, "confluent, costa-septal rays. The epithecal walls are rudimentary "or absent, the internal walls are generally distinct, cylindrical, "floor slightly developed, and crossed by one styliform columella, "and may be defined as a confluent *Lithostrotion*, with external "walls wanting."

In Sedgwick and M'Coy's "British Palæozoic Fossils" (p. 110), the species of *Phillipsastræa* are placed amongst the Sarcinulidæ, while Lamarck places them in the Acervularian group; and one of the forms which d'Orbigny called *Phillipsii* must be placed among the Acervularias.

H. Milne Edwards and J. Haime ("A Monograph of the British Fossil Corals," p. 203) enumerate the names of the authors who designate their *Phillipsastræa radiata* as follows:—

"*Erismatolithus tubiporites* (*radiatus*)—W. Martin, 1809.

"*Tubipora radiata*—S. Woodward, 1830.

"*Astrea Hennahii*—Phillips, 1841.

"*Sarcinula placenta* and *S. Phillipii*—M'Coy, 1849.

"*Phillipsastrea Hennahii*—D'Orbigny, 1850.

"*Phillipsastrea radiata*—Edwards and Haime, 1851.

"*Sarcinula Phillipsii* and *S. placenta*—M Coy, 1851.

"Corallum massive, astræiform with a flat surface. Calices "irregularly placed; their edges very slightly prominent, and "their central fossula rather deep; columella slender, compressed, "and in general not very distinct, septo-costal radii almost "completely confluent exteriorly, 24 or 30 in number, very thin, "and becoming alternately unequal in size near the walls, where "some of them terminate. Diameter of the calices about 1½ line; "depth, one-half the diameter. A vertical section shows that the "walls are somewhat indistinct; the visceral chambers are closed "by large, concave, somewhat irregular *tabulæ*, and that the "vesicles occupying the intercostal loculi are small, irregular, "twice as high as they are broad, and arranged pretty regularly "in horizontal rows."

M'Coy (*op. cit.*, p. 110) gave the name provisionally to a coral which he believed to be identical with the Flintshire one figured by Prof. Phillips, but not named nor described. It is closely allied to *Sarcinula placenta*, but is of thicker growth; the tubes are one-third larger, usually less than their diameter apart, and surrounded

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by 32 to 40 strong radiating lamellæ extending to the adjoining tubes. There is an obvious tendency in the middle of the transverse diaphrams to extend and form an irregularly-compressed solid axis, often visible in the weathered cups. In his description of *S. placenta* he states that this form bears a strong external resemblance to *Nemaphyllum decipiens* (M'Coy), but is distinguished by having no divisional lines between the stars in either section.

Billings, in the "Fossil Corals of the Devonian Rocks of Canada West," gives the following description of *Phillipsastræa Verneuili*, E. & H. :—"This species forms large flat masses, with the surface "covered with stars about half an inch in diameter. The cup is "usually 3 lines wide, with a rounded margin from which the "surface slopes in all directions to the contiguous corallites. "There are between 35 and 45 radiating septa minutely denticu-"lated or striated in their edges, with from 6 to 10 ridges or "spines in one line. When the cup is empty the inner surface is "nearly perpendicular and vertically striated by the free edges of "the radiating septa. It is often filled by the rough projecting "termination of the pseudo-columella."

Dr. Schäfer states that "Kunth has already explained all that "has been mentioned so far. He has also given (*loc. cit.*,* p. 30, "tab. 1, fig. 4) an exact description of *Phillipsastræa Hennahii*, "Lonsd. (=*Smithia Hennahii*), which contains many valuable "remarks, especially in reference to the microscopical structure. "In this species the calyx shows a false columella ('columellarian "'tubercle,' as he himself adds in parenthesis), but the sections "show no columella. Kunth, therefore, doubts the correctness of "making the presence of a columella a distinction between the "genera *Phillipsastræa* and *Smithia*; moreover, according to "Messrs. Edwards and Haime, *Smithia* also has on the tabulæ a "columellarian tubercle, and in *Smithia Hennahii* and *Smithia* "*Bowerbanki* they mention 'lobes paliformes,' such as might "produce a similar structure in the calyx to that shown in the "figure of *Phillipsastræa Verneuili*."

"Kunth, therefore, arrived at the following conclusion :—There "is no generic distinction between *Phillipsastræa* and *Smithia* so

* "A. Kunth, Beiträge zur kenntniss fossiler Korallen, Zeitschrift der "Deutschen geologischen Gesellschaft, vol. xxii., p. 30, Berlin, 1870."

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"far as the presence or absence of a columella is concerned; a "columella might perhaps be present in *Phillipsastræa Verneuili*, "but in this case it would have to be shown in a section. "Consequently the four species separated under the name *Smithia* "by Messrs. Edwards and Haime must be referred back to "*Phillipsastræa* and the name *Smithia* must be abandoned."

"In the year 1876 Rominger* gave a description of *Phillips-* "'*astræa Verneuili*, in which he says:—'The centre of the calyx "'bottom is raised into a columellar knot, and in vertical sections "'of calcified specimens a central string of greater density can "'be observed, but it is not a solid axal column; in some species "'no indication of a columella is perceptible.' Thus it was clearly "shown in a section, that the only species about which doubt "still existed—*Phillipsastræa Verneuili*—did not possess a "columella. Therefore, Rominger also united the genus *Smithia* "with *Phillipsastræa*. In the generic diagnosis of *Phillipsastræa* "he says (*loc. cit.*, p. 128)—'The longer lamellæ unite in the "'centre and form a pseudo-columellar, nodular protuberance, "'but do not connect into a continuous vertical axis.'"

"Since this time, therefore, Lindström, C. Ferd. Romer, v. Zittel, "and others have united the genera."

"Mr. James Thomson,† however, who in 1883 described certain "species of *Phillipsastræa* from the Carboniferous rocks of Scot- "land, remarks that the species in question possesses a columella. "Of *Phillipsastræa radiata* he says (*loc. cit.*, p. 395)—'there is a "'central compressed prominent columella in some coralets,' and "further, 'in a longitudinal section the tabulæ are irregular; some "'are rectangular, but the greater proportion are bent upwards "'and meet in the centre and form a more or less discontinuous "'columella.' His figures, however (*loc. cit.*, pl. iv., fig. 1, 1*a*, 1*b*), "show no columella, only in one single corallite (pl. iv., fig. 1) four "septa are seen to meet. Neither does the longitudinal section "show any columella. Of *Phillipsastræa tuberosa* he says (*loc. cit.*, "p. 396)—'the corallum is mammillated, and there is a stout "'laterally-pressed columella.'"

* "C. Rominger, Geological Survey of Michigan, Lower Peninsula, "vol. iii., pt. ii., Palæontology, Corals, p. 128, pl. xxiii., fig. 2, New York, "1876."

† "J. Thomson, On the Development and Generic Relations of the Corals "of the Carboniferous System of Scotland. *Proc. Phil. Soc. Glasgow*, "vol. xiv., p. 394, Glasgow, 1883."

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"It is evident that if Mr. Thomson were correct in stating that "*Phillipsastræa radiata* and *Phillipsastræa tuberosa* really possessed "a columella, then the union of *Phillipsastræa* and *Smithia*, as "proposed by Kunth and accepted by subsequent writers, would be "incorrect; on the contrary, both genera would have to be main-"tained in the sense in which they were proposed by Messrs. "Edwards and Haime."

Thus the structural characters which collectively distinguish *Phillipsastræa* of Edwards & Haime, are (1) non-existence of the inter-mural investment of the corallites; (2) confluence of the septa; (3) presence of a columellarian boss in the calicular cavity; (4) irregularly formed tabulæ, some being flat and at right angles to the perpendicular of the central tube, others more or less elevated towards the centre, others elevated and acuminate, uniting with similarly-elevated lamellæ from opposite sides, and forming the conical boss so frequently found occupying the centre of the corallites; and (5) reproduction by submarginal gemmation. As regard the affinities, the genus has been associated with—

Erismatolithus tubiporites (*radiatus*)—W. Martin, 1809.
Tubipora radiata—S. Woodward, 1830.
Astrea Hennahii—Phillips, 1841.
Sarcinula placenta and *S. Phillipsii*—M'Coy, 1849.

From the above it will be apparent that these authors rest their generic definitions upon structures totally at variance with each other. Without entering into minute details I shall give a brief description of the series lying before me, and trace how far the species agree with Dr. Schäfer's observations on the types of Edwards and Haime. I am sure I may express the thanks of every palæontologist to Dr. Schäfer for his careful examination of these types, and those of M'Coy, as recorded in his valuable paper above mentioned. The different structural aspects therein described arise, I am convinced, from the examination of some of the specimens from the under aspect upwards instead of downwards. In the former case the interseptal dissepiments cannot be otherwise than concave, while in the latter they are convex, and from the same cause other structural details will be similarly misrepresented. This is well exemplified in a specimen in the Public Museum of Liverpool in which the section is shown from below upwards, and the calices are downwards.

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Phillipsastræa radiata—E. & H.

(Plate V., figs. 1, 1*a*, 2, 2*a*, 2*b*, 2*c*, 2*d*.)

Specific Characters.—Corallum composite, in broad thick astræiform masses, and composed of corallites more or less vertical; development by fissiparity; the calicular fossa 2½ mm. deep, 6 mm. in diameter, and from 10 to 12 mm. apart from centre to centre of neighbouring corallites. A portion of the septa are confluent on one side, while on the opposite side of the corallum they are considerably shorter and recurve at their union with the outer extremities of neighbouring corallites. One septum of the latter is considerably shorter than the others; and the interseptal space is broader and deeper, the only indication of a fossula. Epitheca thin, developed on the under side of the corallum, and there are broad and shallow annulations of growth. From 14 to 16 primary septa alternate with an equal number of secondary ones. Along the lateral margins of the septa are a series of mural pores about one mm. apart, with prominent raised lips, giving a crenulate aspect to well-preserved specimens. In the floor of the interseptal spaces, at the junction of the convex interseptal dissepiments, there is a large elongate pore, with a raised lip on one side, resembling a little hood. The lamellæ of the septa are delicate and indistinct, and their sclerodermic tissue is minutely granular. In the slab the section is from (Plate v., fig. 2*a*) there are 76 corallites, 55 of which show a more or less prominent columellarian boss, with ribbed ridges, which spring from the endotheca of the calicular fossa. In 14 calices this boss is minute; and in 9 the tabulæ are flat, and there is no protuberance. In the longitudinal section the tabulæ are irregular, a small proportion being rectangular; but the greater proportion are bent upwards, uniting in the centre, and forming a more or less discontinuous columella, which in some form is seen extending from the inferior to the superior extremity of the corallum. In the interior of the calicular fossa the inner extremities of the septa are exposed, extending downwards as keeled ridges. The interseptal spaces are closed in by elongated convex cellular tissue, with the convexity inwards and pointing upwards, and the lamellæ which form the conical boss are seen to rest, and spring

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from the interlamellar dissepiments forming the endotheca of the calicular fossa.*

Formation.—Lower Carboniferous.

Locality.—Found at Blackridge, Dumfriesshire, in a bed of shale interstratified with thin bands of limestone in which *Productus giganteus* is found.

Phillipsastræa tuberosa—M'Coy.

(Plate V., figs. 3, 3*a*, 3*b*.)

Specific Characters.—Corallum composite, astræiform, upper surface of the corallites more or less mammillated and minutely granular. In well-preserved specimens the septa are delicate, a portion being semi-circular and others confluent, while on the opposite side of the corallites they are considerable shorter. One of these is half the length of the others, and the interseptal spaces are larger and deeper; this I regard as the interseptal fossula. Mural pores with raised lips, about ½ mm. apart, developed along the lateral margins of the septa. Interseptal dissepiments convex, and between each there is a comparatively large elongated pore. There are 14 to 16 primary septa alternating with an equal number of secondary ones, the latter not extending to the endotheca of the calicular fossa. The former pierce and descend along the endotheca of the calicular fossa as keeled ridges. The corallites are from 10 to 16 mm. apart from centre to centre of neighbouring corallites. In a slab with 150 corallites, in which the calices are 2 mm. deep and 6 mm. in diameter, the columella is prominent in 105; in 45 the columella is less prominent, while in a few it is scarcely seen. In another specimen the corallites are 3 mm. deep, the columella is prominent and laterally compressed, which, in a weathered specimen, is shown

* When in Liverpool at the meeting of the British Association in 1896, Dr. Rickets, of Birkenhead, kindly permitted me to examine the specimens of *Phillipsastræa* in his collection. I also examined one specimen in the Liverpool Public Museum, and Mr. Joseph Lomas afforded me an opportunity of examining a specimen in the Liverpool University collection. A friend forwarded to me from Corwen, North Wales, specimens of *Phillipsastræa radiata* and *P. placenta*, in all of which mural pores are very distinctly exposed, and in the latter much more minute and more abundant than I have previously seen in any of the species. They are somewhat less than a mm. apart. Their interseptal pores are developed similar to those found in Scotland, and with corroborative evidence so pronounced, I have no hesitation in placing the results of my investigations before palæontologists.

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extending upwards, and forming the axis of the corallum. Indeed, if examined alone, this might be regarded as a different species, the superior extremity being so unlike that of the former, but it can only be regarded as a variety. In the transverse section the septa are bilamellar, more pronounced in those corallites in which the section is near the surface, arising from the union of the convex interseptal dissepiments with the lateral margins of the septa; while in the other parts these dissepiments are shown as convex cellular tissue, the convexity along the lateral margins of the septa. Upon the whole, *P. tuberosa* cannot be regarded as simply a variety.

Formation.—Lower Carboniferous.

Locality. — In chocolate coloured shale interstratified with thin bands of limestone in which *Productus giganteus* is found, at Blackridge, Dumfriesshire.

Phillipsastræa clissiophylloides.—THOMSON.

(Plate VI., figs. 1, 1*a*, 1*b*.)

Specific Characters.—Corallum composite in concave astræiform masses, corallites being from 6 to 10 mm. apart from centre to centre of neighbouring corallites. Calicular boss prominent and conical; the lamellæ extend from the endothecal tissue upwards to the apex; corallites are 2 mm. deep, and 6 mm. in diameter. Around the margin of the calicular fossa is slightly elevated, and in this respect it approximates to the aspect of *P. tuberosa*, the corallum being never so large, nor is the mammillar aspect so pronounced. Septa stouter and coarsely granular, projecting at their inner termination into the calicular fossa, and descending along the inner margin of the fossula as keeled ridges. The lamellæ of the conical boss rest upon the endothecal tissue, and ascend as ridges to the apex of the boss in the centre of the calicular fossa. There are from 15 to 18 primary, alternating with an equal number of secondary septa; a portion is confluent; the large majority is considerably shorter, being arrested and united with the septa of neighbouring corallites. One only half the length of the others, and the interseptal space deeper and wider, and this I regard as the fossula. Minute mural pores along the lateral margins of the septa, and those in the floor of the interseptal spaces not so large as in the interseptal spaces of the

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succeeding species. In a transverse section the interseptal dissepiments are smaller, irregular, and more or less angular than in *P. radiata*. In the longitudinal section, if along the centre of the calicular fossa, a columellarian line is frequently present, the interspaces being closed in by convex interlamellar dissepiments which rest upon the endotheca, and extend upwards and to the apex of the columella in the centre of the fossa. Interseptal dissepiments convex, and occupy the space between each corallet, those on the margin of the fossula being less convex, and descending sharply downward forming the endotheca of the calicular fossa. Increase by fissiparity. Upon the whole, the corallites are more numerous than in *P. radiata*, its nearest ally, and the structural details are more delicate. The sclerodermic tissue is minutely granular.

Formation.—Lower Carboniferous.

Locality.—Found at Blackridge, Dumfriesshire, associated with *Productus giganteus*.

Phillipsastræa placenta—M'Coy.

(Plate VI., figs. 2, 2*a*.)

Specific Characters.—Corallum compound, astræiform, increase by fissiparity, corallites from 6 to 10 mm. apart from centre to centre of neighbouring corallites; corallites slightly gibose. Central fossa moderately deep, usually 2 mm., and about 5 mm. in diameter; septa stout and coarsely granular, there being from 12 to 14 primary, alternating with an equal number of secondary septa. Minute mural pores one mm. apart along their lateral margins, and on the floor of the interseptal spaces at the junction of the interseptal dissepiments there are comparatively large pores. A portion of the septa are confluent, three-fourths being much shorter, and uniting with the septa of neighbouring corallites. One of the latter is fully half the length of the others, and the interseptal space is deep and broader, the only indication of a fossula. The primary septa extend further into the calicular fossa, and the keeled ridges are more prominent along the inner face of the fossa than in any of the other species; the lamellæ of the conical boss are shown springing from and resting upon the endotheca of the calicular fossa. In the longitudinal section the conical protuberances are periodical, while in the transverse

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section the interspersed flat tabulæ are shown in the proportion of one in four of those in which the conical boss appears. In the transverse section the septa are delicate, and the interseptal dissepiments are smaller and more irregular than in any other species of the genus. Upon the whole the specific characters are pronounced and distinct.

Formation.—Carboniferous.

Locality.—Blackridge, Dumfriesshire, found associated with dwarfed specimens of *Productus giganteus.*

Phillipsastræa fasciculata.—THOMSON.

(Plate VI., figs. 3, 3*a*, 3*b*, 3*c*.)

Specific Characters.—Corallum astræiform; calices 1 mm. deep, and fully 4 mm. in diameter; central boss acutely dome-shaped; the lamellæ are more or less fasciculate, extending inwards and uniting in the centre of the calicular fossa. Septa coarsely granular, with mural pores along their lateral margins; there is a large pore at the union of each of the convex dissepiments forming the floor of the interseptal spaces. Interseptal dissepiments larger and more irregular than shown in any of the other spaces; corallites variable in size; a portion of the septa confluent, three-fourths being considerably shorter; one about half the length of the latter with deeper interseptal spaces, which I regard as the fossula. From 14 to 17 primary, alternating with an equal number of secondary septa. In a longitudinal section, where the central area is exposed, a delicate columellarian line is shown; the interlamellar dissepiments are convex, and spring from the endothecal dissepiments, converging inwards and upwards, and forming the conically-formed boss in the centre of the calicular cavity. This species differs from *P. clissiophylloides*, var. *stellata*, its nearest ally, by the lamellæ, the convex interlamellar dissepiments uniting the lamellæ of the central boss, and the larger and irregularly arranged interseptal dissepiments. The forms represented in Plate vi., figures 3*b*, 3*c*, I regarded for a time as specifically distinct, but after procuring a large number of specimens, my examination revealed that the series was connected by intermediate forms so closely allied that I could only regard figures 3*b* and 3*c* as having varietal distinction, though not sufficiently pronounced to warrant them being raised to the rank of varieties proper.

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Formation.—Lower Carboniferous.

Locality.—Found at Blackridge, Dumfriesshire, associated with *Productus giganteus.*

Phillipsastræa clissiophylloides var. *stellata.*—THOMSON.

(Plate VI., figs. 4, 4*a*, 4*b*.)

Specific Characters.—Corallum composite in flat astræiform masses; composed of shallow corallites. Calicular fossa about 1 mm. deep, 7 mm. in diameter, and from 10 to 12 mm. apart from centre to centre of neighbouring corallites. Increase by fissiparity; septa delicate; from 14 to 16 primary, alternating with an equal number of secondary ones. About a fourth are confluent, the others considerably shorter, one of the latter being about 3 mm. long; one of the interseptal spaces broader and deeper, and is the only indication of a fossula; epitheca thin and developed on the under face of the corallum; there are broad annulations of growth. In well-preserved specimens elongate obtuse conical spines are developed along the summit of the septa, and elongate minute mural pores along their lateral margins; in the floor of the interseptal spaces at the junction of the interseptal dissepiments the pores are larger. The longitudinal section shows the columella in the centre of each corallite and the lamellæ resting upon the elongate and downwardly inclined dissepiments, which form the dense endotheca of the calicular fossa. The sclerenchyma of the septa, and interseptal dissepiments, are minutely granular.

Formation.—Lower Carboniferous.

Locality.—Found at Blackridge, Dumfriesshire, associated with dwarfed forms of *Productus giganteus.*

The combination of characters presented in the genus *Phillipsastræa*, the non-existence of a mural investment, and the confluence of a portion of the septa, are so distinctive of generic identity as to satisfy the most fastidious observer. The discovery of mural pores along the lateral margins of the primary septa will, however, remove all doubts as to the relationships of *Phillipsastræa* and *Smithia.* Some of the forms, it is true, may be regarded as more or less of a passage character, considering the non-continuity of the structural details, but similar conditions are observed in every group of forms belonging to the Carboniferous system. The non-continuity of the columellarian rod in some forms, and the

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intervention of the flat tabulæ in others, is not confined to this genus, as similar conditions are present in several other genera.

In *Phillipsastræa radiata* a portion of the corallites have the tabulæ rectangular, and there is no central protuberance. In the longitudinal section, however, the flat tabulæ are shown resting upon the endotheca of the calicular fossa (Plate v., fig. 2*c*). In another portion of the same corallites the lamellæ (not tabulæ) of the conical boss are either superimposed upon the flat tabulæ or are attached to the endothecal tissue of the calicular fossa at varying inclinations, giving the columellarian area a more or less vesicular character (Plate v., fig. 2*d*), while in others the columellarian line, in the centre of the vesicular tissue, is shown extending from the inferior to the superior extremity of the corallite. These conditions may be more frequent in some corallites than in others (Plate v., fig. 2*d*), but in no instance have I found the extension of the septa into the centre of the calicular fossa as adduced by Dr. Schäfer. If we carefully examine well-preserved specimens it will be found that the lamellæ of the conical boss spring from the endothecal tissue of the fossa. In those instances where the lamellæ are in contact with the inner extremity of the primary septa they are seen to overlap, and are fused to the lateral margins of the septa, for an extension of which they may thereby readily be mistaken. Indeed, the structural details of the central area more or less resemble those of some species of the genera *Cyathaxonia* and *Lonsdalia*, in respect that the columellarian area is more or less vesicular. In transverse sections of the latter the lamellæ are observed to spring from and to rest upon the tabulæ of the interlocular area, whereas in *Cyathaxonia* the columella is frequently cylindrical and vesicular, and in some forms is minute and scarcely visible. It is true that in some forms of *Phillipsastræa* the conical boss and columellarian rod are not continuous, and are frequently interrupted by the intervention of the rectangular tabulæ, and this may with some reason be raised as an objection to the establishment of generic identity. But if such is accepted as a valid reason for their deletion, similar objections could be adduced against the acceptance of several species of *Koninckophyllum* and one species of *Diphophyllum*. In each the continuation of the columella is periodical, and not continuous, but in all other

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respects the structural details of the genera predominate, as in those species of *Phillipsastræa* in which the tabulæ are frequently interrupted; the continuation of the columellarian rod, and alone can the prevailing structural details be accepted as being sufficient to warrant generic identity.

Prof. Schäfer further remarks—"Where the tabulæ are conical "and bent upwards, the weathered surface appears mammillated, "whilst the surface is almost flat where the tabulæ are more "horizontal. Since gradations exist between the different kinds "of tabulæ, we must expect to find on the surface of weathered "specimens all varieties between smooth and mammillated calyces."

Such an explanation of the varied external aspects is not applicable to the specimens examined by me. We have forms with flat tabulæ, the corallites being convex around the calicular fossa, or more or less mammillar, whilst in *Phillipsastræa clissiophylloides* the conical boss is more pronounced and occurs more frequently than in any other species, and the greater number of the corallites are all but flat, and some even concave. I cannot therefore accept Prof. Schäfer's explanation of the mammillated aspect of the corallites and their relation to the conical protuberance in the calicular cavity. Such is not borne out by the Scottish forms, nor by those I examined in Liverpool. Indeed, in some of the most prominent mammillated forms, as in *P. tuberosa*, the tabulæ are horizontal, and in some cases concave.

Microscopic Structure.

Prof. Schäfer states that "the septa are formed of bundles "of calcite fibres, which lie on either side of the median plane of "the septum. From this starting point on this plane each fibre "passes upwards and outwards in the direction of the proximal "end of the septum."

In all the sections of Carboniferous corals which I have examined, many thousands in number, I have in no instance found such a feathered aspect in the sclerodermic tissue, it being in all cases minutely granular both in the septa and in the interseptal dissepiments (Plate V., fig. 1). Indeed, such a feathered aspect in the structure is only represented by the arrangement of the minute corallums in the genus *Monticulipora*, these, however, presenting the calices externally; whereas the structure as represented

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in Prof. Schäfer's sections indicates a biological character unknown in the morphology of the tissue of the polyps.

He further states—"The difference of structure between the "septa on the one hand, and the vesicles and tabulæ on the other, "arises chiefly through their having originated in a different "manner in the living animal. If we consider that as the living "animal grows upwards it secretes the tabulæ and vesicles beneath "itself, we shall see that the latter structure must have the same "histological origin as the sclerobasis; that is to say, it is the "secretion of that part of the ectoderm which invested the deepest "parts of the calicular fossa. In the tabulæ and vesicles then "the calcification could only take place from below upwards; the "septa, on the contrary, were arched over by the ectoderm, "and the calcification could continue both upwards and on "either side."

From this we can only infer that the intercellular calcite, and the granular tissue of the septa and interseptal dissepiments, were segregated at various elevations. In all the coralline forms I have examined, there is no evidence of such a condition; indeed, we have coralline remains from the Carboniferous system in which the intercellular spaces are still unfilled. The septa and interseptal tissue consist of the usual granular tissue, while the intercellular spaces are in a similar condition to that found in recent corallums. Indeed, all our experience points to the conclusion that the intercellular calcite was secreted posterior to the segregations of the granular sclerenchyma of the septa and other structural details of the corallum.*

As formerly stated, in order that the evidence might be as full and clear as possible, I again visited the only locality where *Phillipsastræa* has been discovered in Scotland. In the absence of either Edwards and Haime's or M'Coy's type specimens, I requested a friend who was visiting Corwen in North Wales to procure for me specimens of the genus from there. He forwarded to me *Phillipsastræa radiata* and *P. placenta*, so that I might not

* In transparent sections there are to be seen, in some instances, minute crystalline bodies at right angles to the trend of the septa. If the sections are not ground sufficiently thin, these bodies appear to have been subsequently crystallized in the intercellular spaces, but when thin enough the granular tissue is observed. Either this cause, or the imperfections of the instrument they are examined with, can alone account for the presence of this unique structural error.

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only compare them with the Scottish forms, but identify their individuality from each locality as far as possible. Those sent from Corwen, North Wales, for comparison are undoubted specimens of *Phillipsastræa radiata* (Plate V., fig. 1), and *P. placenta* (Plate VI., fig. 2), showed clearly that there was not only specific distinction, but, that other species distinctly different were also found in this Scottish locality. They further convinced me that in many instances the designation of both genera and species from descriptions alone has been a fertile source of error and confusion. The Welsh specimens were well-preserved, and after being carefully cleaned, revealed in both species pronounced specific distinction, and further along the lateral margins of the septa mural pores in excellent preservation similar to those in the Scottish forms. This will necessitate the group being transferred from the Cyathophyllidæ into the Favositidæ. Well-preserved specimens also clearly show that the septa do not extend to the centre of the calicular fossa, but spring from, and are attached to, the endothecal tissue of the axal fossa. For the purpose of comparing the Devonian species of *Smithia* with the Carboniferous species of *Phillipsastræa*, as regards their relationship, I have failed to procure the desired specimens of the former. In the Liverpool Public Museum I was permitted to examine *Smithia Hennahii* (Lonsdale), and saw, though I had only a cursory examination, that there was no generic relationship. Indeed, the presence of the delicate mural investment of each corallite was of itself sufficient to satisfy any palæontologist on this point. The same may be said of *Acervularia Goldfussi* (de Varn.), which is even more pronounced in its generic difference.

In the absence of the types or identified specimens of *Smithia* for comparison, but from a knowledge of the careful and accurate work of Edwards and Haime, in conjunction with the fact that the specimens were in the collections of such able observers as Mr. Bowerbank, Dr. Battersby, and Mr. Pengelly, and all of Devonian age, I am sure that from the descriptions and the delineations of the structural details there was a similarity. But the clavate termination of the septa, and the indicated palii at their inner extremities in *Smithia*, have long satisfied me that Edwards and Haime's deductions were well founded, and more especially from a knowledge that Messrs. Bowerbank and Pengelly were

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conversant with the distinctions of the structural details of both genera.

May I be permitted to ask Dr. Schäfer whether the evidence he possesses warrants the acceptance or rejection of variation as a probable reason for the varied and conflicting opinions expressed by the able observers referred to. To treat this inquiry properly a long catalogue of those opinions ought to be given, but to do so would be beyond my limits. Neither shall I further discuss the various definitions of what constitutes a species. No one has satisfied all naturalists, though each author has defined his conception of a species. The term "variety" is mobile and more or less vague, whilst it implies community of descent. If examined singly a specimen might have been, and has been, regarded as a species, but when examined in a connected series, it may be found to exhibit structural details merging into and uniting forms so closely that it becomes difficult to define specific distinction. There are also abnormal forms brought about by causes beyond our knowledge which must be considered.

The diversity of generic names applied to this group of corals, in which generic distinction is so pronounced, and whose external aspects are so unlike those of any other group, is highly suggestive. From this it will be inferred that the group includes a series easily to be distinguished from all the other coralline remains yet discovered in the Carboniferous system, and this induces me to believe that the diversity of generic and specific definitions could only have arisen from both genera and species having been described by some authors, not from the actual examination of the corallums themselves, but from the descriptions of other writers. It is also apparent that not only some of the authors of the past, but also those of more recent times, have relied more upon external aspects than upon microscopic observations.

But the question as to how and why these divergent opinions have been brought about may be dismissed at present. My province is with the specimens in my possession. The definitions of Edwards and Haime are so pertinent and clear as to induce me to accept their deductions as eminently satisfactory, so far as the Carboniferous forms are concerned. Since their time many new facts have been brought to light, which simply

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necessitate the addition of later discoveries, without interfering with their definitions. Some of these additions may be accepted as follows:—

1st. The corallum is astræiform and the corallites are diversified.

2nd. The epitheca is developed on the underside of the corallum, and marked with annulations of growth.

3rd. The septa are of two orders, more or less confluent, and mural pores are developed along their lateral margins.

4th. The primary septa merge inwards, project, and extend downwards as keeled ridges along the face of the theca of the calicular fossa, and the secondary septa converge inwards, and are attached to the lateral margin of the primary septa, near the lip of the calicular fossa.

5th. The interseptal spaces are closed in by convex interseptal dissepiments, while those around the margins of the fossa curve sharply downward and form the thecal tissue of the calicular cavity.

6th. A conical boss is usually present in the calicular fossa in varied proportions.

7th. In the longitudinal section the continuation of the conical boss in some forms is interrupted by the intervention of transverse tabulæ; in others it is continued throughout the whole extent of the corallum, and the lamellæ and interlamellar dissepiments are either sharply inclined upwards, or are more or less convex, become united to the centre line, and present a more or less vesicular columellarian boss in the centre of the calicular cavity, which in some forms projects in the calice, whilst in some it is minute, and in others is not present. In other forms the central area is occupied by either a stellate or a fasciculate arrangement of the lamellæ, which spring from and are attached to the endothecal tissue of the fossa. An interseptal fossula is indicated.

Upon the whole, the genus *Phillipsastræa* as demonstrated by the specimens found in Scotland may readily be recognised by the partial confluence of a portion of the septal system, by the existence of a more or less conspicuous columellarian boss in the centre of the fossa, and by the coalescence, centrally, of a portion of the lamellæ which ascend from the endothecal tissue of the calicular cavity to the centre of the calices. I have been

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unable to trace the supposed relationship of *Phillipsastræa* of the Carboniferous system to the genus *Smithia* of the Devonian system in any of the species of *Phillipsastræa*, either from North Wales, or those discovered in Scotland.

EXPLANATION OF PLATES V. AND VI.

Plate V.—Fig. 1. *Phillipsastræa radiata* (E. & H.). Transverse section, from Haford-y-Calch, Corwen, North Wales.

,, 1*a*. ,, ,, Enlarged section of corallite showing granular tissue of structural details, from Haford-y-Calch.

,, 2. ,, ,, Natural size.

,, 2*a*. ,, ,, Transverse section, nat. size.

,, 2*b*. ,, ,, Another variety, nat. size.

,, 2*c*. ,, ,, Longitudinal section, nat. size.

,, 2*d*. ,, ,, Do. of another part of same corallum, showing the different structural details in columellarian area, from Blackridge, Dumfriesshire, nat. size.

,, 3. *Phillipsastræa tuberosa* (M'Coy), from Blackridge, nat. size.

,, 3*a*. ,, ,, From another slab, nat. size.

,, 3*b*. ,, ,, Transverse section, nat. size.

Plate VI.—Fig. 1. *Phillipsastræa clissiophylloides* (Thomson).

,, 1*a*. ,, ,, Transverse section, nat. size.

,, 1*b*. ,, ,, Do., from Blackridge, nat. size.

,, 2. *Phillipsastræa placenta* (M'Coy). Transverse section, nat. size.

,, 2*a*. ,, ,, Do. showing the variable structure in same species, from Blackridge, nat. size.

,, 3. *Phillipsastræa fasciculata* (Thomson).

,, 3*a*. ,, ,, Transverse section of another specimen, nat. size.

,, 3*b*. ,, ,, External aspects of another specimen, nat. size.

,, 3*c*. ,, ,, Transverse section, from Blackridge, nat. size.

,, 4. *Phillipsastræa clissiophylloides*, var. *stellata* (Thomson.)

,, 4*a*. ,, , Transverse section, nat. size.

,, 4*b*. ,, ,, Longitudinal section showing columellarian line from inferior to superior extremity of corallum, from Blackridge, nat. size.

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1a

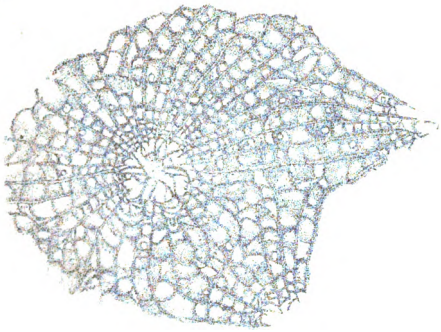
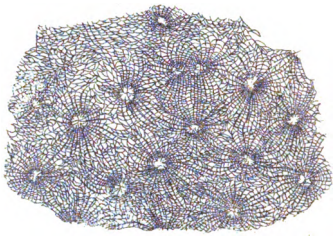


Fig. 1



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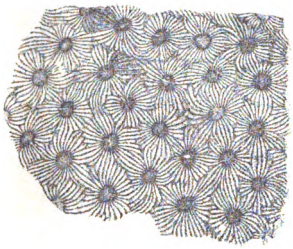

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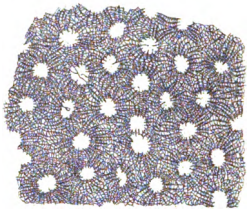

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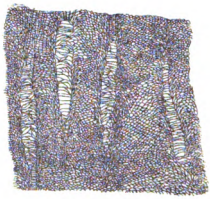

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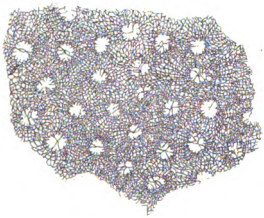

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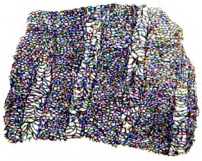

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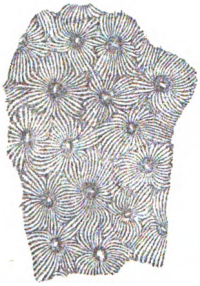

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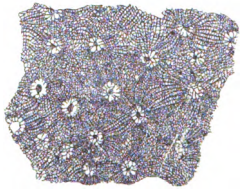

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Robert Thomson, Del.

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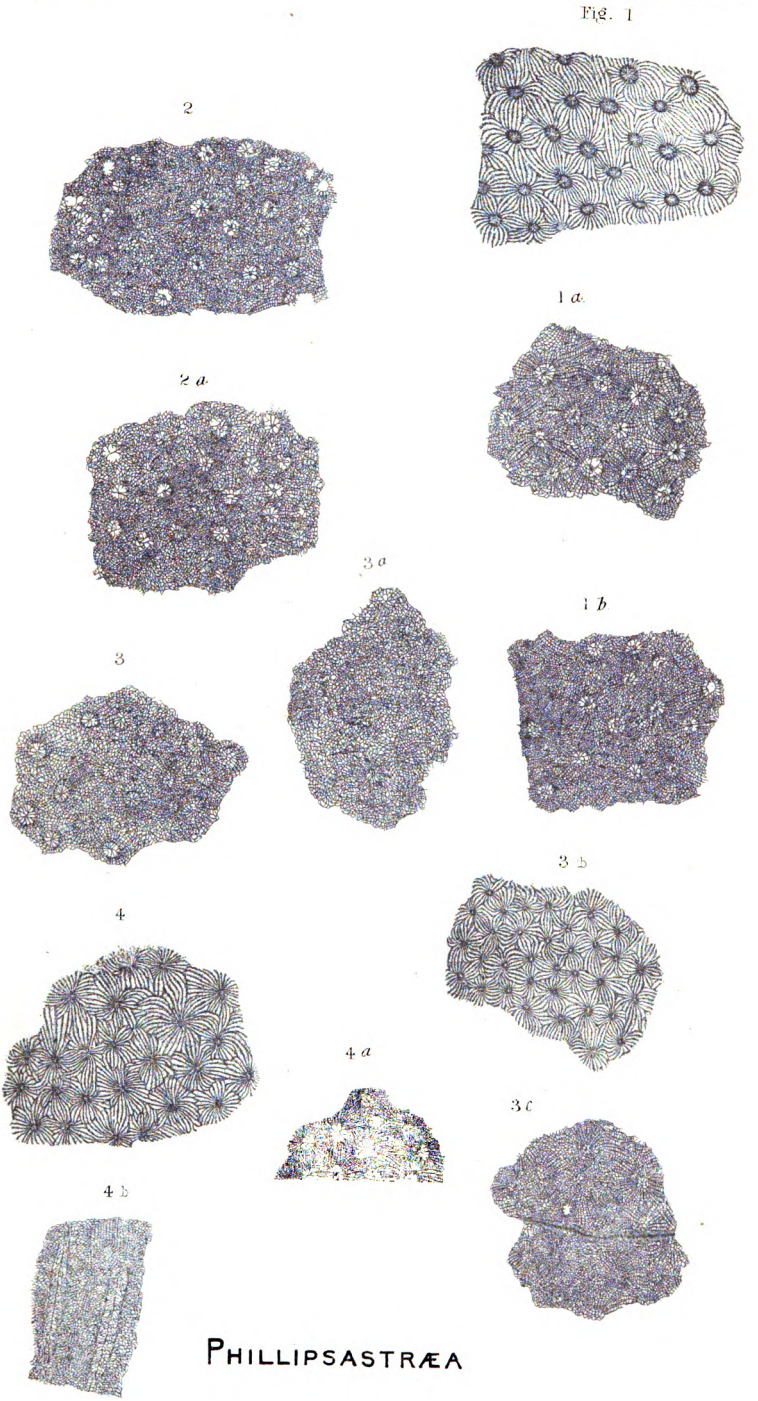

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No. VI.—Desert Conditions in Britain. By J. G. Goodchild, H.M. Geological Survey, F.G.S., F.Z.S., M.B.O.U., Curator of the Collections of Scottish Geology and Mineralogy, Edinburgh Museum of Science and Art.* With a Plate (No. VII.).

[Read 22nd April, 1897.]

Introduction.—Amongst the geographical mutations which each part of the earth's surface has undergone in past times, the change of climatal conditions from those of a humid type to others in which extreme aridity has been the most prominent characteristic, has occasionally had a place. Even in Britain it has more than once happened that meteorological conditions of the type which we are accustomed to regard as normal, so far as rainfall is concerned, have given place for a time to climatal conditions differing in no essential respect from those which prevail in desert regions at the present day.

By desert conditions, as here understood, is meant that combination of geographical conditions which has led to certain parts of the earth's surface receiving a smaller annual precipitation than suffices for the maintenance of any types of vegetation except those specially adapted by evolution to an environment in which aridity is the dominant feature. As typical examples of the conditions referred to may be cited the Sinaitic Peninsula, parts of Afghanistan, the great Central Asian deserts, as well as the more arid parts of western North and South America. As regards *temperature* these regions differ widely from each other; whence it will be seen that the prevalence of excessive sun-heat is by no means a special characteristic of desert regions.

In one respect all areas of inland drainage may be regarded as areas where desert conditions prevail. Under the existing geographical conditions of the earth's surface the areas of inland drainage occupy an area of 11,486,350 square miles,† which, as the area of land draining into the ocean is estimated‡ at 44,211,050 square miles, makes the proportional area of the one to the other

* It should be noted that another version of this paper was given as the Opening Address to the Edinburgh Geological Society on 19th Nov., 1896 (see *Transactions* of the Society), also to the Philosophical Society of St. Andrews in the same year; and at Bangor and Perth in 1897.

† Dr. John Murray, *Roy. Scot. Geog. Mag.*, vol. iii., p. 75.

‡ *Op. cit.*

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about as one to four. Dr. Murray gives as the total area of the ocean 141,243,300 square miles. The area of inland drainage, therefore, is to the area of oceanic drainage about as one to fourteen. If we assume that the various geographical conditions of the earth's surface in the past periods of its history were, taking one time with another, combined in different regions of the globe in much the same proportion to each other as they are now, we might expect to find records of marine conditions amongst ancient rocks from twelve to fifteen times as frequently as we should find records of conditions of inland drainage. As a matter of observation, this is about the proportion which the rocks formed in past times under conditions of inland drainage are known to bear to those formed in the sea.

Dr. Murray defines desert conditions as those which prevail where the annual rainfall does not exceed 10 inches, and his figures* give 12,214,250 square miles as the area where these climatal conditions obtain. I should be disposed to modify this definition to a certain extent, and to include under areas of desert conditions all those areas where the total quantity of aqueous vapour normally present in the air is much below the average. These conditions may prevail where the rainfall exceeds 10 inches; for it may happen that the total quantity of rain precipitated during occasional thunderstorms may amount to considerably more than that, and yet periods of several months, and even years, may elapse without more than an occasional shower falling there, and the rainfall therefore be quite insufficient for the needs of vegetation. Arid conditions of this nature are usually due to the fact that the regions where they prevail lie inland in relation to great mountain areas, over which the chief moisture-bearing winds have passed. Such upland areas act as condensers, and wring every available drop of moisture out of the clouds that pass over them, leaving little or none to be transported to the areas on their lee side. The mountains of Judæa act in this way, and intercept the moisture from the clouds before they reach the country to the east of the Jordan valley, which, mainly on this account, receives very little regular rainfall, and hence is converted into a region of deserts.

Rock Disintegration under Desert Conditions.—Two results of

* *Op. cit.*, p. 74.

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considerable geological importance arise from arid conditions of the kind under notice. Firstly, in a region where the rainfall is either low, or very irregular in its occurrence, vegetation of almost every kind fails to retain a permanent footing. As a consequence, sooner or later, large tracts of country, which, under normal conditions of climate would be covered with soil, speedily become bare and tend to remain in that condition; animal life, also, tends to be but poorly represented. Furthermore, the absence of any vegetable covering permits the solar energy to act upon the soil with its fullest force, because none of the sun's rays are used up for the vital processes of the plants themselves. Secondly, in a region where the percentage of aqueous vapour present in the air is below the normal, both insolation and radiation attain to much higher extremes than where these conditions are different. It is a well-known fact that the presence of aqueous vapour in the air tends to act as a screen to the sun's rays during the day, thereby very materially tempering their effect upon rock-surfaces, and that it tends equally to act as a blanket by night, checking the radiation from the earth to a very important extent. Where the amount of moisture present in the atmosphere is but small, the sun's rays exert their maximum power, and heat up the rock-surfaces to their fullest extent within a comparatively short time. In like manner the absence of the blanket formed by the moist air permits of the rocks cooling down to a very low point with equal rapidity. In arid tropical regions rocks, stones, and sand, heat up by about 2 P.M. to temperatures so high that the hand can scarcely bear to touch them, while by about 3 A.M. the air in contact with these same rocks may be at or below the freezing point. In arid regions, even within the temperate zones, the effects of insolation and radiation are hardly less marked, and the diurnal range of temperature to which the rocks are subjected is considerably greater than that which can possibly obtain in more humid regions.

In Walther's "Die Denudation in der Wüste und ihrer Geologischen Bedeutung," the chapter devoted to the diurnal range of temperature in Egypt and the parts adjoining is full of interest in this respect.* Not to enter into details here, it may suffice to point out some of the consequences of geological interest

* Page 359, *et seq.*

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which arise from an excessive diurnal range of temperature such as prevails under these conditions. In Britain and other countries where humid conditions prevail, the expansion of rocks caused during the day by sun-heat does not, as a rule, proceed beyond the mean, and the rise of temperature and the consequent expansion of the rocks take place gradually. In like manner the fall of temperature, and the consequent diminution of volume of the rocks, are also moderate and take place nearly always at a slow rate. Consequently the effects of insolation and radiation are with us factors in denudation of no more than secondary importance. They are certainly of much inferior importance as factors in denudation to the effect of such chemical causes as the solvent action of rain-water charged with the humus acids, and their ultimate term, carbonic acid. The difference between arid and humid conditions, especially where the waste of limestones and rocks of eruptive origin is concerned, is most marked and important. In the case of arid conditions the diurnal range of temperature, which may amount in extreme cases to as much as 130° Fahrenheit, splinters and shatters the rocks into angular fragments (some of which may be of several tons in weight), at the same time leaving them almost entirely unaffected by any changes of a chemical nature. In the other case, that of denudation under humid conditions, the waste of the rock is chiefly accomplished by means of chemical changes—the mechanical effects being usually quite subordinate to those which have been accomplished by chemical decomposition. Limestones in arid districts splinter off from the parent mass in angular blocks, which show no sign of chemical erosion. Under humid conditions the same rock rarely weathers away in such forms, but presents abundant evidence of being fretted and corroded by the acidulated waters, whose action terminates only in the entire solution of the rock and its transportal seawards as bicarbonate. In like manner eruptive rocks under humid conditions disintegrate chiefly by the decay of the felspars, from which the alkalies are removed in solution in combination with CO_2. Under arid conditions these rocks splinter off in angular fragments, whose constituents, and especially whose felspars, remain quite fresh and not in the least kaolinised.

In desert regions, therefore, the absorption of carbon dioxide

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from the atmosphere which takes place under humid conditions, both by the action of plant life and by the formation of carbonates in the case of the rock-forming minerals, is reduced to a minimum. Probably as much carbon dioxide is given off from the earth, especially in the vicinity of volcanoes, under these, as under other geographical conditions; so that it must be assumed that the unused balance of this gas must rapidly find its way elsewhere under the joint action of the wind and the diffusive force of the gas itself. But this side of the subject does not appear to have been as yet at all investigated.

Another factor of importance in the present connection relates to the constitution of eruptive masses. These, of course, usually consist of three or more crystalline minerals, together with, in some cases, an interstitial ground mass. Supposing for argument's sake, that these minerals are felspars of two kinds, with quartz and hornblende, we have a rock whose constituents are different from each other, not only in their chemical, but also in their physical properties. Their specific heats are different, so that under a given temperature they warm (or cool) unequally in a given time. Their rates of expansion for a given rise of temperature are not only different amongst themselves, but are different in different directions for each mineral. Hence, with a rapid change of temperature every twenty-four hours, the unequal expansion and contraction to which the rock as a whole is subjected, loosens the cohesion, not only of the several minerals to those adjoining, but, in the case of the hornblende, tends to splinter the mineral into fine threads which are easily removed from the wasting rock even by a gentle breeze. The felspars split along their dominant cleavage planes and fall away from the rock, retaining, however, as they do so, their faces as bright and fresh as if they had been newly hammered out of a perfectly sound piece of rock. No such freshness or angularity of felspar fragments is possible as a result of weathering under humid conditions.

Thus it arises that, in arid regions, eruptive masses waste in a totally different fashion from what they do in humid areas. Their ferro-magnesian silicates disintegrate under insolation, and are blown away by the wind, instead of decomposing into soluble carbonates and an insoluble residue. Their felspars are

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not resolved by decomposition into carbonates of the alkalies and residual kaolin, but simply break up into fresh and perfectly angular fragments, which, as screes, slide down the mountain sides in the direction of the bottom of the valleys. The quartz, detached from its matrix, suffers at the most but a mechanical reduction in size. Much the same happens with the accessory minerals, such as zircons, magnetite, rutile, &c., which are afterwards separated out by the wind, or by floods, and left as heavy residues.

In course of time an occasional thunderstorm bursts over the area, the screes are washed to the bottom of the valley or wady, and are there levelled out by the temporary flood. Then follows a period of drought, during which the wind takes up the work of deposition, and spreads out the finer materials in more or less horizontal layers over the torrent débris just before brought down. In this way well-stratified alternations of arkose* and finer rock-material, largely consisting of sand, with occasional layers of the heavier mineral residues, are being formed in the wadys of desert areas of the present day.

The prevalent tendency of desert denudation is to reduce inequalities of the surface, and not to create valleys. Wadys are therefore, in all cases, the effect of running water, and must have been formed by rivers, under climatal conditions of a normal or humid character which formerly occurred where these valleys are now. Excellent examples of the phenomena referred to are to be seen in the Sinaitic Peninsula.† In that area the Nubian Sandstone, &c., formerly overspread a nearly level tract formed of gneisses and granitoid rocks. These rocks, subsequently upheaved into great plateaux, were for a long time exposed to the denuding action of rain and rivers at the time when humid conditions prevailed in that area. Deep and wide valleys were thus excavated. Then came a gradual change of meteorological conditions which ended by substituting humid for arid conditions, and in the formation of deserts. The rocks there no longer

* The term *arkose* should be restricted to those conglomerates or breccias whose constituents include angular fragments of fresh felspar. The arkoses of the Torridonian rocks are typical in this respect.

† An extensive series of photographic views of these wadys and the geological phenomena they illustrate, was projected by the lime-light on each occasion when this Address was delivered.

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weather in their former fashion, but now splinter up under the alternate expansion and contraction due to the high diurnal range of temperature. Angular quartz-grains and angular pieces of perfectly fresh felspar now break away from the mountain sides, while the dark mica and the hornblende blow away as fine black dust, leaving the heavier mineral residues in places by themselves. Screes accumulate on the sides of the wadys, until one of the torrential rains, by which such regions are occasionally deluged, descends upon them, when the loosened material is transported to the bottom of the wady as torrent débris, and is spread out by the floods in rudely parallel layers, over which afterwards dunes are drifted by the wind and are eventually levelled out. I shall endeavour to show, in the concluding part of this Address, that conditions very similar to these here described have more than once or twice obtained within the limits of what are now the British Isles.

Eolian Denudation.—In a region where the rainfall is low, or where there are long intervals of drought, it usually happens that the wind becomes a much more important agent in both denudation and deposition than it usually does in humid climates like our own. As regards denudation it is well known that large quantities of the finer rock-material, loosened by prolonged exposure to insolation, are drifted far and wide by the winds. In course of time such driving showers of sand produce considerable abrasion of the rock-surfaces, undercutting crags, shaping isolated masses into strange, mushroom-shaped forms, pitting the rocks, and carving out niches, deep recesses, and caves, which as the process is continued, are sometimes enlarged to considerable dimensions. Some very curious examples of these features are figured in Walther's book already referred to; [and a fine series of views of such rock-surfaces, etched by natural sand-blast, in various parts of the Arabian Peninsula and in Egypt, was exhibited by lime-light when this Address was given.] I have long taught in my geology courses of lectures that it is highly probable that the first rough shaping of the Sphinx itself was due to causes of this nature; and that the ancient Egyptians merely improved upon an idea suggested in the first instance by the natural form of this remarkable object.

On a small scale good examples of the kind of surface produced

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by the action of natural sand-blast may be found in many localities. Many of our torrs, for example, largely owe their characteristic form to eolian denudation. But in Britain it is chiefly in the neighbourhood of maritime tracts of sand that the peculiarly pitted, furrowed, and polished surfaces of rocks, worn by the action of those natural sand-blasts, can be most conveniently studied. At Hound Point, near Dalmeny, on the Firth of Forth, one such surface of dolerite has long been known, and often visited. Others equally good are to be seen at North Berwick, while the well-known Ardross dyke, between Elie and St. Monance, on the Fife coast, is perhaps as good an example as can be met with anywhere. A very characteristic set of these effects of eolian denudation from many British and some foreign localities, including the desert regions of Africa, is exhibited in the Geological Index Collection of the Edinburgh Museum of Science and Art.

The sand-grains, by which this eolian denudation, or afflation, is accomplished, themselves undergo considerable wear in the process. They, too, become pitted, furrowed, smoothed and rounded, in the process. As the features referred to possess considerable importance in the present connection, and as, moreover, the means by which the wearing of grains of sand is accomplished are by no means commonly understood, it may be as well to devote a few lines here to the consideration of the process.

The Shaping of Grains of Sand.—In the shaping of sand-grains, whether the operation takes place upon land or under water, three principal factors are concerned. The most important of these factors is solar energy, which supplies the heat necessary for evaporation and other physical processes, and which sets the winds and the waves to work and thereby furnishes the chief motive power. In opposition to this form of energy is the almost equally-important force of gravitation, which, in the cases specially under consideration here, may be regarded as continually striving to counteract the work accomplished by solar energy. These two factors are, indeed, those to which we may ultimately trace nearly all the causes which are concerned in geological operations. The third form of energy, which, although in general of very subordinate importance when compared with the other two, is of special interest in the present connection, is that known

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as surface tension. Its nature is at present very imperfectly understood; but that part of it which relates to the transport, the reduction in size, and the shaping, of rock-material, will need to be considered in more detail presently. In the meantime it may be useful to remind the reader of the operations of the other two factors, solar and gravitational energies:—solar energy converts water into aqueous vapour and elevates the product, in opposition to the force of gravitation, to points which may be as much as several miles above the surface of the ocean from which that vapour has been distilled. The same form of energy, setting the winds in motion, drifts that aqueous vapour from its parent source landward. Coming into contact there with the cool surface of mountain tops, the vapour condenses into either rain or snow, giving up as it does just as much heat as was employed in the first instance in the distillation of the quantity condensed. Then, exclusively under the influence of gravitation, it descends from the level to which it had been elevated by solar energy, flows downhill and seaward, expending, as it does so, some of the remaining energy it derived from the sun almost entirely in accomplishing geological work of one kind or another, most of that work consisting in the downhill and seaward transportal of material removed from the surface of the land. The transporting medium may be ice, air, or water: the *modus operandi* in each case being different, though the final results may be nearly the same.

We may conveniently notice first that mode of transport in which water is the medium employed. In order to understand the bearing of this upon the subject of the present Address we need briefly to consider the principles which govern the transport of rock-material, and especially those which relate to the superficial area and the weight of stones undergoing transportal in any given medium, taking water as that medium first. The ratio between the superficial area and the volume (and therefore the mass) of solid bodies of similar figure needs to be considered first. The *surfaces* of bodies of similar figure, but different in size, vary as the square of their linear dimensions. For example, the surface of a cube 1 inch by the side presents an area of 6 square inches, while that of a sphere of the same diameter is 3·14159 (&c.) square inches. If the linear dimension of the cube

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be doubled, its surface area is increased in the proportion of $2 \times 2 \times 6$, *i.e.* 24 square inches; while the same increase in the case of the sphere augments its superficial area in the proportion of $2 \times 2 \times 3{\cdot}1416$, *i.e.* 12·566 square inches. If the one-inch cube be reduced to a cube half-an-inch by the side, its surface area is diminished from 6 square inches to an area of $1\frac{1}{2}$ inch. A sphere with a diameter of 1 inch has a surface area of 3·14159 square inches; while if it be reduced to half that diameter its surface area will diminish to ·78539 of a square inch.

But, in the case of *volumes* of bodies with similar figure that differ in size, it is well-known that these volumes increase as the cube (or decrease as the cube root) of their respective linear dimensions. A spherical stone 1 inch in diameter has a volume of ·5236 of a cubic inch (and a surface area of 3·1416 square inches); but if that stone be worn down from a diameter of 1 inch to that of $\frac{1}{2}$ an inch, its volume is diminished to ·06545 of a cubic inch (its surface area, as already mentioned, being ·78539 of a square inch). This is one way of stating the fact that bodies of similar figure, with enlargement of dimensions, increase in volume, and therefore in weight, much faster than they increase in surface; or that, with reduction of dimensions, they decrease in volume, and therefore in weight, faster than they decrease in superficial extent. To put this into yet simpler language, one may say that, when a grain of sand is being worn down, its surface area does not lessen so fast as its weight does, but becomes proportionately larger; in fact, with each halving of the diameter of a sphere the ratio of its surface area to its weight is doubled.

If this principle is now made clear we may pass on to consider one of its applications, choosing, in doing so, a quotation from Sorby's well-known Address to the Geological Society of London.* "The friction [of a sand-grain†] upon the bottom must be always small . . . and must vary as the weight, and therefore as the cube of the diameter; but the surface from which the material must be worn varies as the square of the diameter. Hence, even making no allowance for the extra buoying-up of very minute particles by a current of water depending upon surface cohesion [or surface tension], the effect of wearing

* *Quart. Jour. Geol. Soc.*, vol. xxxvi., pp. 32-33.

† The words in square brackets are the present author's own.

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upon the form of sand-grains must vary directly as their diameter, or thereabouts. If so, a grain $\frac{1}{10}$ of an inch in diameter will be worn ten times as much [in travelling a given distance] as one $\frac{1}{100}$ of an inch in diameter, and at least a hundred times as much as one $\frac{1}{1000}$ of an inch in diameter [travelling that distance]. . . . A grain $\frac{1}{10}$ of an inch in diameter will be worn as much in drifting a mile as one $\frac{1}{1000}$ of an inch in being drifted 100 miles."

The surface cohesion alluded to by Sorby is now more generally known by the name of surface tension. Some idea of its nature may be gathered by studying the phenomena that often accompany the pouring of fluids out of earthenware vessels provided with lips or spouts. Pouring tea out of a glazed earthenware teapot shows this, in many cases, remarkably well. In the hands of those not accustomed to perform this household duty, the tea, which is meant to fall in a graceful curve from the spout into the tea-cup, will, instead of doing so, persist in running a variable distance along the underside of the spout, whence it eventually drips off from the vessel at a point far removed from that which was either expected or desired. A study of this homely illustration will enable us to realise the fact that there are evidently in this case two independent sets of forces at work: gravitation (if it be not interfered with) tends to make the tea drop perpendicularly from the end of the spout; while some other force of a different kind is evidently counteracting that of gravitation, and is tending to make the tea adhere to the surface of the glazed earthenware, and so to remain in contact with the teapot as long as possible. This force is that of surface tension. The course taken by the fluid is readily seen to be one compounded of motions arising from the joint-action of gravitation, surface tension between the tea and the teapot, and between the tea and the air, and the impulse given at the outset by the operator.

Surface tension, illustrated by this example, operates in nature in a great variety of ways, acting, indeed, between every fluid and any solid with which that fluid may be in contact. The results differ very materially according to the respective natures of both the fluid and the solid. They differ in the case of the contact of the same fluid with different solids, and in that of the same solid in contact with different fluids. Moreover, in the operation

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of natural causes, the effect is further complicated by the ratio which the bottom velocity of the transporting medium bears to the superficial area, the weight, and the durability, of the material acted upon, as well as, of course, upon the distance the particles travel, or the time during which the forces remain in operation.

Much reliable information upon this subject is given in Sorby's Address already mentioned, also in Daubree's "Géologie Experimental," and in J. A. Phillips' article "On the Physical History of Grits and Sandstones."* The present writer is also indebted to his friend Professor Heddle of St. Andrews for valuable information upon this as upon many other geological topics, and especially to an address on "Sand," which he gave before the Edinburgh Field Naturalists in 1896.†

It follows from these considerations that, in the process of wearing down a grain of sand by friction, under the impulse imparted by fluids in motion, surface tension becomes more and more effective in proportion as the surface area of the grain increases relatively to the weight. Eventually a stage of reduction is reached at which the adhesion between the moving fluid and the grain is sufficient to counteract the opposing effect of gravitation. When that is the case the grain is buoyed up by the fluid and is carried forward as if it were part of the fluid itself. After this, further rounding of that grain in that particular medium is no longer possible. Hence the grains of sand which have been shaped as such in either sea-water or river-water undergo no further rounding after they have been reduced below certain dimensions determined by the factors above mentioned. The minimun size is said to be about $\frac{1}{250}$ of an inch.

Like water, air is a fluid, and there is exerted between a given sand-grain and the atmospheric air surrounding it a certain amount of surface tension too. But this adhesive force is very much lower than it is in the case of water; consequently gravitation acts with more effect. This is another way of stating the fact that sand-grains impelled by the air will tend to be rolled against other sand-grains, and to be bowled along in contact with rock-surfaces, long after their size has been reduced to that of

* *Quart. Jour. Geol. Soc.*, Feb. 1881, pp. 6-27.

† Since these lines were in type Dr. Heddle has died, and Geology has lost one of its most active pioneers.

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Fig. 1. Desert Sand from west of Cairo.
(× 10)

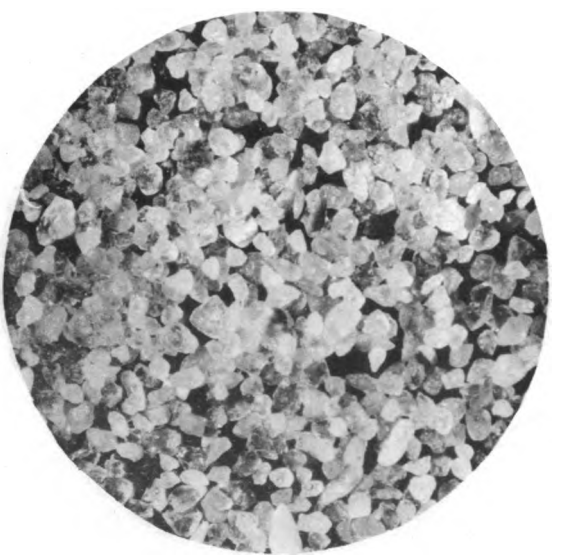

Fig. 2. Sea Sand from Eigg.
(× 10)

From Photo-Micrograph by Wm. Forgan.

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the smallest which the action of water of any kind could possibly round. Given, therefore, the necessary conditions and sufficient time, and wind is capable of reducing sand-grains of almost all sizes into a more or a less spherical form, by prolonged friction against each other, and against surfaces of rock. As a matter of fact this is exactly what does happen. The long-continued rolling and drifting to which desert-sands have been subjected by the action of the wind ends by shaping a large proportion of the sand-grains into smaller spheres. The spherical form of the grains and their pitted and polished surfaces are thus distinctive characteristics of desert-sands, and are never seen in any sands which have been shaped by either rivers or the sea.

This difference in form between sea-sand and desert-sand is well illustrated by the photomicrographs shown in the accompanying Plate [No. VII.]. In fig. 1 is an example of sea-sand ("the musical sand"), from Lairg Bay, Eigg, in which the grains are sub-angular; in fig. 2 is shown the form of the sand-grains from the desert area to the west of Cairo, obtained for the author by Mr. William Crawford, F.R.S.E. Both were photographed by Mr. W. Forgan. Fig. 2 is somewhat more highly magnified than that of the sea-sand, and it will be observed that in this case all the larger grains are well rounded.

One of the characteristic modes of accumulation of desert-sands is in the form of dunes, which are often of considerable size. The longer axes of these dunes are said to range, in a great many cases, north and south, as if that direction were determined by the earth's rotation. False bedding at exceptionally high angles is another characteristic of the layers formed of desert-sand; and it is said that the dominant direction of these false bedding planes inclines from the east westward, as if, again, the earth's rotation had something to do with it. Ripple-marks are of very common occurrence in recent desert-sands. It has been stated that these ripple-marks may be distinguished from ripples formed under subaqueous conditions by the fact that in the desert-sand ripples the coarsest grains occupy the *crests* of the ripples instead of lying in the troughs. This feature has not yet been investigated in connection with the fossil desert-sands, to which special reference will presently be made.

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Rocks accumulated under desert conditions at any period in the earth's history may be expected to exhibit some, or all, of the features just described, if geologists are correct in assuming that geographical conditions in past times did not differ essentially from those which are met with on one part or another of the earth's surface now. Just as areas where desert conditions prevail now are characterised by special types of denudation, and by equally well-marked types of deposition, so we may reasonably expect to have been the case in the past. And, reasoning back from effects to causes, we are quite justified in referring to a desert origin any ancient accumulations whose general character conforms to that characteristic of desert regions at the present day. Thus if we meet with an association of ancient screes and torrential deposits, consisting of angular and quite unweathered rock-materials (now forming breccias and arkoses), with strongly false-bedded sands whose component grains show the rounded form and pitted surfaces like those due to long-continued rolling under subaërial conditions, and if these deposits lie upon an exceptionally uneven surface, or fill up old wadys, we are, it seems to me, perfectly justified in referring the rocks in question to a desert origin.

Subaqueous Deposits.—But there are two collateral sets of facts which have an important bearing upon questions of this nature, both of which afford confirmatory evidence of an important character. One of these, which we may notice here now, relates to deposits formed under subaqueous conditions in connection with the wide and shallow lakes, or "schotts," of desert regions, as well as with those formed in bodies of deeper water, such as are represented by the Dead Sea and similar lakes. Into such lakes, when they are situated in the vicinity of areas of desert sand, this eolian deposit may be transported by the action of the wind, and mingled in considerable quantities with the deposits proper to the lake. Furthermore, rivers of small volume discharge into these shallow lakes water whose matters in solution have already been partially concentrated by evaporation under arid conditions.

Amongst the substances carried down in solution by rivers in all parts of the world are some few that merit special consideration in the present connection. The principal of these are—(1) chloride of sodium, which, carried up into the air in the form

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of sea-spray during storms, is drifted inland, forms the nuclei of rain-drops, and thence descends to the land. Under ordinary circumstances this chloride of sodium completes the cycle of change by flowing back, in rivers, to the sea; but under desert conditions the aqueous medium in which it is dissolved is returned to the clouds by evaporation, while the salt is left behind to accumulate until its precipitating point is reached, when it is thrown down in the solid form, and thereby constitutes the deposits of salt so commonly found in desert regions. (2) Other sea-salts, especially magnesium chloride, which is also derived mainly from sea-spray. (3) Carbonate of lime, magnesia, iron, &c., dissolved from the rocks of the land through the medium of the humic and allied acids and carbonic acid. With these are various sulphates, as of lime, iron, &c., also derived from the land drained by the feeders of the lake. In addition to the substances carried down in solution are the remains of animals and plants drifted down in suspension. The proportion in which these latter will occur is, of course, largely determined by the nature of the climatal conditions prevailing within the basin of the rivers draining into the lake. Into the Dead Sea, for example, large quantities of vegetable matter are annually transported by the Jordan; while in other river-basins, where the conditions do not happen to be so favourable for the growth of vegetation in their upper parts, the quantity of organic matter transported to the terminus of the streams may be reduced to almost none at all. But in other areas the quantity of organic matter may be very small. The same is true of fishes and other forms of animal life. It will presently be shown that these organic substances exercise very important influences upon the nature of the chemical deposits taking place under these conditions.

In regard to the history of rock-salt, gypsum, dolomite, and their associates, which have been found under conditions arising from those under notice, I do not propose to dwell in this Address.* But, in dealing with the evidences of desert conditions

* Their origin has been already discussed by the present author in various Papers printed elsewhere. See *Transactions of the Cumberland and Westmoreland Association*, *Proceedings of the Geologists' Association*, *Transactions of the Edinburgh Geological Society*, and *Proceedings of the Royal Physical Society*.

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in the past, there are three substances which afford important evidence in relation to the history of British rocks. These are magnesia, iron, and the bituminoids. Probably, in the first instance, the two first-named (like lime) have primarily originated from the decay of eruptive rocks. Under normal, humid, or pluvial conditions, these substances find their way to the sea in the form of bicarbonates, which state they reach through the solvent action upon the rocks of water charged with CO_2 and the allied humic acids already referred to. But in areas of inland drainage, where the whole of the water carried down by rivers is dissipated by evaporation, these substances in solution are left on the spot, and gradually accumulate (like the salt, gypsum, and dolomite), until their respective points of precipitation are reached, when they are thrown down in the solid form. In the case of such areas of inland drainage, some of the carbonate of magnesia either becomes converted on the spot into dolomite, through combination with carbonate of lime, or else it soaks down through the porous strata in which the lake is situated. On meeting with any calcareous matter, even in the solid form, it begins by entering into combination with it, and finishes by converting part, or the whole, of the carbonate of lime into dolomite. This is one very characteristic feature connected with these deposits formed in inland lakes. It is of considerable importance in the present enquiry, as the dolomitisation of limestones is amongst the commonest results arising from strata having been covered by rocks of desert origin, as I have repeatedly pointed out on former occasions.

The history of the ferrous carbonate has been dealt with by Mr. Hudleston in his Presidential Address to the Geologists' Association.* His summary of the chief points of interest leaves almost nothing unsaid with which a geologist is interested. I therefore give part of it here nearly in the author's own words, and enclosed within square brackets :—

[Iron liberated from eruptive rocks is carried away in solution as *bicarbonate*, which is disseminated through the waters of the lake. The part next the surface seizes upon an additional molecule of oxygen in the proportion of Fe_2O_3. This causes it to lose

* *Proc. Geol. Assoc.*, vol. xi., No. 3, p. 104.

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its carbonic acid; but the ferric oxide thus formed immediately combines with water to form the ferric hydrate, and then sinks to the bottom. Portions of such accumulations are from time to time re-dissolved, owing to the abstraction of the extra molecule of oxygen by the carbon of *decaying vegetation.* This extra molecule of oxygen helps to form the CO_2, or other humus compounds, which dissolve the iron, now reduced to the protoxide. In this way the game of solution and precipitation is kept up indefinitely, and where the balance is in favour of precipitation an accumulation of iron ore will occur. Reduction renders iron soluble and locomotive; oxygenation arrests locomotion and fixes the iron on the spot. Iron is a base, with a strong affinity for the humic acids, and their ultimate term carbonic acid. It has also a strange affinity for oxygen, and in the presence of this it forms the nearly indestructible (and, in the *absence of organic matter*, almost insoluble) ferric oxide.

As ferric oxide in the *presence of organic matter*, it provides the oxygen for decay, and its residuary protoxide is itself dissolved by the resulting organic acid, and enters into circulation. . . . Red rocks have been coloured in the first instance by solutions of ferrous carbonates and sulphates depositing the insoluble peroxide, and, for lack of reducing agents in sufficient amount, the iron of these beds has not been rendered soluble, and therefore remains disseminated instead of being concentrated. . . .]

Some very characteristic petrographical features of minor importance also arise in connection with the shallow bodies of water which occur in connection with areas of inland drainage. The shores of these waters are usually very shallow, so that, with a slight lowering of general level, a large surface of mud and silt is bared and left to dry. Air-breathing vertebrates, wandering about in these shallows and across the half-dried surfaces, very commonly leave well-marked spoors, generally in the shape of footprints. Over these sand is occasionally distributed by the wind, and this layer of sand, in its turn, is almost as often again covered by succeeding layers of mud. In this manner natural casts of the footprints are taken, and may eventually be hardened into stone and so be preserved for long ages.

Or a shower of rain may pelt the surface of the half-dried clay

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and indent it with impressions of rain-drops. Sand blown over these protects them from destruction, and they, too, may become fossilized and last as long as the footprints.

More often it happens that the surface of the clay left by the temporary desiccation of a pool dries; it then curls up into small polygonal slices, with concave upper surfaces, and separated from each other by cracks. These desiccation-cracks are usually confined exclusively to beds of clay, and they descend from the surface of the dried-up mud only as far as the material is purely argillaceous in character. If the surface is quickly flooded thereafter, before any other deposit is laid down, these dried and curled-up flakes usually float away, much as leaves would do under like circumstances. In this form the flakes of mud may eventually subside to the bottom, perhaps at a point a considerable distance from where they originated. Such flakes of mud form shale-galls, which are common features in all deposits found in shallow water, whether under conditions of inland drainage, or in lagoons, or even in wide estuaries. If, however, sand be blown over a sun-cracked surface of clay before it is softened and swelled by water, this sand will fill up the cracks and take casts of the moulds formed by the concave surfaces between the cracks, and in this way preserve the casts, which thus serve as records of the conditions under which the rocks were formed. It is important to note that it is only *blown sand* which can thus take casts of desiccation-cracks.

Other features of interest occurring in connection with these shallows of inland lakes are the curious lumpy excrescences which often arise in connection with shallow-water deposits, where bubbles of marsh or other gas arising from decomposing organic matter, or from chemical changes of any other kind, reach the surface. Small blisters, and also pipe-like cavities with trumpet-shaped mouths, often arise in this way.

Lastly come the effects of chemical inflorescences, and the changes which often follow the development of crystals of various salts, chloride of sodium in particular. Pseudomorphs of chloride of sodium are, indeed, amongst the commonest of the petrographical features of rocks formed in areas of inland drainage.

Another feature, usually associated with the foregoing petrographical characteristics, is the presence of variegated or poikilitic

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mottling in sandstones and marls. This is partly due to the local reduction of the ferric oxide by particles of organic matter, and partly, in other cases, to the replacement of the ferric oxide by the pale green ferrous silicate. In some few cases glauconite has been formed, and gives rise, by its bright green colour, to strong contrasts with the normal red of the sandstone. Such colouration cannot take place under marine conditions; and its presence in rocks may safely be taken as proof of their formation in closed bodies of water, usually in connection with areas of inland drainage.

Hydro-carbon Compounds.—The next point that claims our attention is the very marked association of petroleum and the bituminoids with strata formed under conditions of inland drainage. A careful study of the reactions described in Mr. Hudleston's paper will make it clear that the precipitation of iron in the form of ferric oxide in inland lakes is one of the results of the absence of any large precentage of organic matter, and especially of matter of vegetable origin. Where much organic matter is present the iron goes back into solution as ferrous carbonate, and is eventually thrown down as ferric hydrate. Where organic matter is rare or absent entirely, and only where that is the case, does the iron go down in the form of ferric oxide. It is precisely under desert conditions that one would naturally expect vegetable matter (and, of course, animal matter too) to be but rarely carried into the "schotts," and, even where that is the case, then only in small quantities. We should therefore be prepared to find that where little or no vegetation exists the strata undergoing deposition would be more or less coloured with the red ferric oxide. Conversely, where we meet with sandstones coloured bright red—especially if these consist largely of rounded grains of sand, and are associated with gypsum, rock-salt, and dolomite, and locally contain angular and unweathered fragments of felspar or of limestone—we may correctly infer from these concurrent facts that we are dealing with strata formed under desert conditions. If the underlying sandstones happen to be carbonaceous, are tinted purple of various hues, and are associated with limestones more or less dolomitised and converted into hæmatite, the inference is considerably strengthened, for the reason given above.

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But it must frequently happen that, owing to changing geographical conditions, a region which at one time was under desert conditions may just previously have been, or may soon after become, a region where the conditions may be described as sub-arid, sub-humid, or even humid. Or it may well happen (as in the case of the basin of the Dead Sea, the Salt Lake, and others) that humid conditions prevail and vegetation flourishes in the upper part of the basin, while the lower part of the same basin may be arid in the extreme. Vegetation flourishes in the humid part of the area, and from that part is transported by rivers to the terminal area of the streams, where the water disappears by evaporation. Three chemical changes of importance—perhaps they may all three be described as changes of a reciprocal nature—arise under such conditions as these:—(1) Ferric oxide ceases to be precipitated, and ferric hydrate goes down in its place. In its turn this brings about a decomposition of the vegetable matter. (2) The sulphate of lime carried into the lake, and there concentrated by evaporation, is decomposed by the vegetable matter, with the concomitant deposition of precipitates of carbonate of lime. The reciprocal action in this case consists in that of the action of weak solutions of sulphates, which in the course of time convert the vascular tissues, and even some of the ligneous matter, into one or the other of the many hydro-carbon compounds—the bituminoids amongst others. Hence the frequent—or all but universal—association of rock salt, gypsum, dolomite, and "abraum salts," with hydro-carbon compounds such as oil shales and others. It is to this solvent action of solutions of sulphate of lime upon subaqueous masses of ligneous matter that I ascribe the bituminous character of such rocks as the Caithness Flags, the alternations of oil shale and precipitated carbonate of lime which form the well-known Burdiehouse limestone, the bitumen of the Dead Sea, the petroleum occurring at so many places within the Aralo-Caspian area, and others. Even the pitch in the Pitch Lake of Trinidad appears to me to be due to the uprise of solutions of sulphate of lime through a subterranean carbonaceous deposit.

Secondary Quartz.—One more point, and then we may pass on to consider some British deposits which have been formed under desert conditions. In the case of strata formed in inland lakes

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many other complex chemical reactions must necessarily arise. Amongst these we may refer to the liberation of silica in solution. It has long been known that weak solutions of silica, such as may arise from the decomposition of fragments of felspar bathing clean grains of quartz, will tend to deposit that silica upon the quartz in a crystalline form, giving rise to what is known as Secondary Quartz. The new quartz is not added on to the old anyhow, or at random; on the contrary, its molecules are so built up as to be oriented in the same direction as were the molecules of the old quartz represented by the sand-grain, so that, under examination by polarised light, the new quartz is generally seen to be in optical continuity with the old. Therefore, although many millions of years may have elapsed since the time when the quartz of the sand-grain was originally formed, and that quartz may have been knocked about, worn, rolled, built up into sandstone, wasted, used up over and over—yet when suitable conditions again set in (as they appear very commonly to have done in the case of sandstones which have been formed under desert conditions), the new quartz tends to restore the old quartz-grain to the crystalline form that Nature's forces, perhaps millions of years before, had intended it should take.

Evidence Derived from the Study of British Rocks.—This preliminary chapter leaves not much to be said in the remainder of the Address. I shall now point out that the combination of results arising from desert conditions, of which the foregoing is a summary, may be found not only in deposits which are taking place at the present day, but also in deposits which at various, and often widely-separated, periods in the past, have been laid down in Britain. Briefly, these periods may be stated to be three in number—(1) The New Red period, which is a convenient general name to include the times when the Trias, and the Dyas (Lower New Red, or "Permian"), were deposited; (2) the Devonian period, when the various Old Reds of Scotland, &c., were formed; (3) and, lastly, the Torridonian period. I need only notice the more salient features of each, and remind those who read this Address, that I proceed all along on the assumption that in this, as in other geological matters, we interpret the Past by the Present. If the geological evidence shows that we have in

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Britain strata of the same kind as those which are now being formed only under desert conditions, then we are justified in concluding that desert conditions prevailed in Britain at the times when the rocks in question were formed.

Evidence Afforded by the New Red Rocks.—While deep-water and marine conditions obtained on the Continent during the time when the Tyrolian and Panormian* (= marine Trias and Dyas) rocks were being formed, inland and continental conditions prevailed in the area now represented by Britain and Western Europe. We have no need to enter into details in regard to this point; it will suffice to remind the reader that the British strata formed during the period in question consist largely of variegated and bright-red sandstones and marls, showing casts of sun-cracks, rain-prints, pseudomorphs of rock-salt, footprints, shale galls, and other evidences of shallow-water conditions. With these are associated, in the area embracing the North of England and the North of Ireland, wedge-shaped masses of magnesian limestone. With the marls are also associated anhydrite, gypsum, and rock-salt, together with occasional hydro-carbons. An inspection of the sandstones shows us that they contain a large percentage of well-rounded grains of quartz, each coated, as a rule, with a thin pellicle of ferric oxide. Plant-remains in the red strata are conspicuous by their absence, while the very strongly-marked false-bedding prevalent in the sandstones over large areas at once recalls the diagonal bedding of desert-sands.

Breccias, consisting of perfectly angular and unweathered fragments, occur as old torrential deposits, left in connection with the buried wadys, and are therefore found on every platform, from the very lowest to the highest. Throughout the whole of these breccias the angular form and the perfectly unweathered aspect of the rock-fragments, which are also often of large size, is most conspicuous. This is equally the case, whether the breccia consists of a tumultuous assemblage of limestone blocks, as is the case in the dolomitic "conglomerate" near Bristol, and again in the "brockram" of the North of England, or whether the breccia consists of fragments of granite, as it does on the flanks of granitic areas in the South of Scotland—for example, near Dumfries.

* These names for the strata referred to were proposed in the *Proceedings of the Royal Physical Society*, Edinburgh, 1897, vol. xiii., p. 284.

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The uniformity of petrographical characters in these New Red breccias points unmistakably to the occurrence of equally uniform meteorological conditions over large areas, and shows very clearly that these conditions indicate the long continuance of an abnormally-dry atmosphere; a conclusion which no one who studies the facts will venture to call in question.

At the base of the New Red there is usually some evidence of an irregular surface, and lines of depression, suggestive of old wadys. In some cases the more extensive of these inequalities may be due to unequal subsidence.

In Westmoreland (and probably elsewhere in Britain) there is unmistakable evidence of the presence of ice—floating ice in most cases; but in at least one case, that which I have recorded in the *Proceedings of the Geologists' Association* for 1889, there is evidence of actual glaciation, shown by the occurrence of stones traversed by true glacial striæ, which have been found in the breccias.

Rock-staining.—Some reference was made in the course of the foregoing remarks to another line of evidence bearing upon the subject of this Address. This relates to vestiges of the former existence of red rocks over areas whence they have since been removed by denudation. These vestiges, which are often of a very striking character and easily recognised, have been left in almost every area which has constituted part of the floor upon which any part of the New Red rocks was deposited. The wide diffusion of these traces of the former presence of the New Red rocks over so large an area formed of the British rocks of prior date to the New Red, is a very striking and significant fact, the full importance of which has, as yet, been far from thoroughly realised by geologists, and has in most cases certainly been misinterpreted. It has to be remembered in considering the matter that the New Red rocks bear the same stratigraphical relation to the rocks of Jurassic age as the Upper Old Red Sandstone does to the Carboniferous rocks. Both may be regarded, stratigraphically, as basement deposits, which in each case were invariably followed, at a much later period, but without any stratigraphical break, by their respective overlying deposits of marine origin. Any trace of the former presence of either of these basement deposits, therefore, carries with it an indication

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also of the former presence of the succeeding marine deposit. Where it is known that the Upper Old Red Sandstone, for example, was deposited, there also followed the Carboniferous rocks. In like manner, where there are traces of the former existence of any member of the New Red rocks, over that spot there were almost certainly deposited the rocks of Jurassic age.

The results just referred to are chiefly those due to the effect of the downward percolation of waters charged with various chemical substances in solution. These solutions emanated from the closed bodies of water which here and there characterised the regions wherein the New Red rocks were deposited. The most important of these substances which were filtered down in the form of solutions were those of iron, sulphate of lime, and carbonate of magnesia. The effects produced by the iron, being the more striking in appearance, may be usefully noticed again here, in a little more detail than was required in the general description. Various solutions of iron salts, percolating downwards through rocks, give rise to colouring effects of different kinds, which vary according to the nature of the solutions on the one hand, and to the composition of the rocks on the other. Solutions tending to deposit ferric oxide, for example, will stain rocks of Carboniferous age very differently, according to whether these rocks consist of limestones, sandstones, or shales; and even within these petrographical types much difference of colour will also result according to whether the rocks affected do or do not contain much organic matter. Sandstones, shales, and fire-clays, associated with seams of coal, oil shale, or black-band, or which are in any way associated with carbonaceous matter, whether in the diffused state or otherwise, are rarely or never stained bright-red, for the reason that the presence of any form of carbonaceous matter brings about an alteration of the ferric oxide to either the carbonate or the hydrated form, separately, or mixed in various proportions. Hence the dull purples, the puces, the lilacs, and the dull browns, of Carboniferous rocks which have been stained by such causes; and hence, also, the marked absence of any truly-red standstones in those which happen to include carbonaceous matter in any form, whether in that of coal-seams, or in any other. Where, on the other hand, thick masses of sandstone occur without much carbonaceous matter, as does

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happen on several platforms in the Carboniferous rocks, these, if covered by the New Red rocks, may have received from them infiltrations of ferric oxide to such an extent that the resulting colouration of the sandstones may be but little inferior in point of brightness to that of the Red Rocks themselves. The Rotherham Rock of Yorkshire is an instance of this kind, the "Whitehaven Sandstone" of West Cumberland is another. In the Dalkeith coalfield, near Edinburgh, we have another excellent illustration of this principle, in which the unproductive sandstones of Roslin happen to have been covered by the New Red. Other conspicuous examples are the Lower Carboniferous sandstones of Northumberland and the Berwickshire coast; and also the "red measures" of Fife, as well as the unproductive masses of sandstone which overlie the coal-bearing Upper Carboniferous rocks of the Western Scottish coalfields. It is now thirty years since I suggested that Professor Phillips' "alternating red sandstone and limestone series" of Westmoreland was nothing else than Lower Carboniferous rocks (Ash Fell beds) stained by infiltration from the New Red; and I have since repeatedly demonstrated to my colleagues and others that the same is true elsewhere. In a great number of cases it will be found that much of the rock called Permian in Britain and on the Continent is really nothing more than Carboniferous sandstone stained by infiltration from the New Red, and that the presence of the red colouring is further connected with the absence of carbonaceous matter in the sandstones so affected. On closer investigation it will, I think, be found in all such cases, that the various shades of colouration referred to are simply a result of the former presence over that spot of the New Red rocks, and, therefore, of the existence there at one time of desert conditions.

Deposits of Hæmatite.—Another result of considerable economic importance which arises from the same cause, and which appears to me to point to the same conclusion as those just noticed, is the occurrence of beds, or other deposits, of hæmatite. In the cases where the solutions of ferric oxide were not as widely diffused as they happened to be where they were traversing thick beds of sandstone, local concentration has often arisen; and this is especially the case where the rock in which the concentration has taken place happens to be of a calcareous nature. In this

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case full evidence shows that the ferric oxide, wholly or in part, actually *replaces* the calcareous matter. Deposits of hæmatite may, of course, arise through other causes; but I am convinced, from long experience of their mode of occurrence in the field, that the majority of British deposits of hæmatite are due to infiltration, are of the New Red age, and, as such, mark desert conditions.

Dolomitised Limestones.—The infiltration of solutions of carbonate of magnesia, due to the action of concentrated solutions upon the ferro-magnesian silicates detached from areas of eruptive rocks by insolation, gives rise to results hardly less striking and significant than those of ferric oxide. Wherever the New Red rocks have overlain beds of calcareous matter, such as limestones, these are locally replaced by ferric oxide, by dolomite, or by both together. The remarkable examples of dolomitised Carboniferous (or other) limestones, so often met with in the vicinity of deposits of New Red age in various parts of the kingdom, are certainly due almost entirely to this cause. Hence, where these beds of dolomitised limestone occur in connection with the stained sandstones and shales, and the deposits of hæmatite, already noticed, they form an additional link in the chain of evidence, whereby the former existence of the New Red rocks, and therefore of desert conditions, at that spot, may reasonably be inferred. An impartial examination of the evidence afforded by many areas of Carboniferous rocks in various parts of the kingdom will eventually, I feel confident, lead geologists in general to the conclusion that these results are much more trustworthy than at first sight might may appear to many. To me they indicate not only the wide extent over which desert conditions prevailed at the commencement of Neozoic times (*i.e.*, during the Permo-Triassic period) in Britain; but they also indicate to me, as I have repeatedly taught during the past twenty or more years, that not only the New Red rocks, but also the Jurassic rocks, formerly covered nearly the whole of Britain—not even excepting the areas formed by what are now the Highland mountains.

Desert Conditions during the Devonian Period.—Much of the evidence referred to in treating of the New Red applies equally to each of the Old Red Sandstones. The rocks usually referred to under these names belong to at least four, if not to five, different

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geological horizons. The lowest of these "Old Reds" consist of a series of red sandstones, which are intimately associated with the Ludlow rocks of Southern Scotland. Their relationships to these latter rocks are, indeed, so close, that more than one geologist has followed Mr. John Henderson of Edinburgh in regarding them as representing simply a particular phase of the Upper Ludlow rocks themselves. Their geological position is similar to that of the Glengariff Grits of Ireland, and that of the Foreland Sandstones of Devonshire.

As the rocks in question occupy a position in the series in regard to which geologists are as yet not quite all agreed, it may be as well, for temporary purposes, to distinguish them by a special name, taken from the locality where they are best seen, and where they were first described by Sir Archibald Geikie. * Sir Archibald's remarks respecting these rocks may usefully be quoted here in order that their stratigraphical relationships may be made clear:—"It thus appears that, between the Grampians and the Cheviot Hills, what has been called 'Old Red Sandstone' consists of three zones—a *Lower*, graduating downward into the Upper Silurian shales; a *Middle*, bounded both above and below by an unconformable junction; and an *Upper*, which shades upward into the Carboniferous rocks." I may add that the inter-relationships of these three "Old Reds" is also most admirably and clearly shown in the sections illustrating the relationship of the Old Red Sandstone volcanic rocks in Sir Archibald's valuable treatise on the "Ancient Volcanoes of Great Britain" lately published. As this Lanarkshire Old Red is separated from the other Old Reds by two of the most important unconformities known in the whole geological series, there is a certain fitness in distinguishing their various sub-divisions by special names, such as I have used elsewhere for these same rocks. These names are the "Lanarkian Old Red Sandstone," applied to the lowest; the "Caledonian Old Red" used for the next; then the "Orcadian Old Red"; and, finally, the "Upper Old Red." The term "Old Red Sandstone" may well be retained as a generic name which embraces the whole series.

In regard to the probable origin of this Lanarkian Old Red Sandstone, a short description may very well be given here, as

* *Quart. Jour. Geol. Soc.*, vol. xvi., 1860, p. 312.

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this case will serve to explain in what manner desert conditions may arise in an area at no great distance from the sea, and thus further illustrate the history of desert-formed rocks in general. The leading idea connected with this explanation appeared in Sir Archibald Geikie's "Old Red Sandstone of Western Europe."* It was subsequently applied to a different case in a paper of mine "On the Stratigraphical Relations of the Skidda Slates,"† and again in "Some Geological Evidence regarding the Age of the Earth."‡ In the present case this explanation may be stated as follows:—Early in the Silurian period the area now represented by the Southern Uplands of Scotland, after coinciding for a long time with a marine area of depression, gradually passed from that condition, first of all into an area stationary for a time, and eventually into an area of upheaval. To understand this we have to conceive of the earth's crust being slowly and very gradually flexed into a series of undulations due to an oblique thrust from the south. This affected not only the rocks beneath the surface, but also the actual surface itself. The axes of the upfolds of the surface may be referred to as *geo-anticlinals*, and these of the correlative downfolds as *geo-synclinals*—the zone between the two, where neither elevation nor depression was in progress, being denominated the *septum*, as was done by Prof. Lapworth in his Address to Section C. at the Edinburgh Meeting of the British Association in 1892. The distance from crest to crest of each earth-wave may be referred to as its *wave-length;* while the height between each wave-crest and its correlative sinus or trough is its *amplitude;* the rate of movement of each wave may be referred to, still using the language of the physicist, as its *frequency*.

Now, earth-movements in general appear to consist of undulatory movements which are most commonly of considerable wave-length, a hundred miles or more usually intervening between one wave-crest and that next to it. Such undulations usually have also very small amplitude, and their frequency may be represented by periods of many thousands of years. Uprises

* *Transactions of the Royal Society of Edinburgh*, vol. xxxviii.

† *Proc. Geol. Assoc.*, vol. ix., No. 7.

‡ *Proc. Roy. Phys. Soc.*, vol. xiii., pp. 295-7.

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and depressions of the land under this type of earth-waves take place with extreme slowness, and the extent of upheaval and of its correlative depression is, comparatively speaking, but slight, so that it may be many thousands of years before an upward undulatory movement changes phase, and gives place to a movement in the opposite direction.

Every gradation probably does exist, or has existed, at one period or another, between these terrestrial undulations of great wave-length, small amplitude, and low frequency, on the one hand, and others of short wave-length, large amplitude and high frequency, on the other. I conceive that, in all cases, the undulatory movement is not a mere up-and-down movement, but that it actually progresses as do waves in general. If the reader can transfer this idea, stated in the language of the physicist, to movements of the earth's crust, and can, further, conceive of an area which for a long time has coincided with a downward phase of earth-movement of great wave-length, small amplitude, and low frequency, gradually becoming the theatre of earth-movements of a more powerful kind, he will have but little difficulty in forming an idea of the kind of earth-movements to which the changes from the marine conditions which characterised Silurian times, to the continental and desert conditions which prevailed in North Britain during the Devonian period, are due.

According to this view, the area where the Lower Ludlow rocks were being deposited in the South of Scotland began to undergo slow and gradual upheaval along a zone probably coincident with a north-easterly and south-westerly line passing through the northern third of the area now represented by the Scottish Southern Uplands. The effect at an early stage was to elevate the old sea-bottom there into land, and to cut off the area immediately to the north entirely from the sea. The elevation proceeding, and gradually extending in area, gave rise to a broad geo-anticlinal, which, gradually taking on the form of a mountain tract, intercepted the aqueous vapour derived from the marine area to the south-west; just in the same way as the mountains of Judæa now intercept the moisture carried eastward from the Mediterranean, and leave winds devoid of moisture to pass over the country lying to the east of the Jordan valley. As a consequence, the part of Scotland referred to consisted geographically

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of (1) a marine area lying to the south-west; (2) a broad upland tract, gradually rising in elevation, and extending as far as the fold extended (an unknown distance) to the north-east and the south-west; (3) to the north of this tract an inland region, bounded on its seaward side by the broad mountain tract just mentioned. Any aqueous vapour drifting inland under these geographical conditions would be chiefly precipitated on the seaward slopes of the mountains, and such of this vapour as passed this zone of condensation would be but small in amount, and insufficient for the needs of vegetation in general. In other words, the mountain ridge separated the sea, in which the Ludlow rocks were in process of deposition, from a continental area to the north-east, in which the desert-formed Lanarkian rocks were in process of deposition. Denudation from the zone of upheaval supplied the wasted material by which the depressed area adjoining was gradually filled up.

While this was in progress the undulatory movements slowly and gradually changed phase, advancing from the south northwards as they did so, and gradually converting areas of upheaval into areas of depression, and the areas of depression one after another, from the south northwards, into areas of upheaval and denudation. It was in this manner, I conceive, that each of the "Old Reds" was formed, and it was under these conditions that arose the strongly-marked and extensive unconformities which separate, for example, the Pentland (Caledonian) Old Red from the Lanarkian Old Red on the one hand, and from the Upper Old Red Sandstone on the other.

It has occurred to me that possibly the sea may have gained admittance for a short time during the formation of the Lanarkian Old Red, and thus have permitted of the formation in Scotland of a limestone of Devonian age. But whether that surmise prove correct or not, it is certain that the continued formation of a series of surface-undulations, gradually propagated from the South of Scotland northwards, permitted of the formation, one after another, of the various Old Reds, and of the unconformities that separate them, right up to the very top of the Upper Old Red.

There is evidence that, during the time when the Orcadian Old Red was in course of being deposited, normal pluvial conditions obtained for a time. The deposition of ferric oxide in the old areas of inland drainage ceased, chiefly in consequence of the large

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quantities of vegetable matter which were swept into the old lakes. This vegetable matter in its turn decomposed the solutions of sulphate of lime, and liberated the calcareous matter which, in a state of diffusion, or segregated into nodules, now forms so conspicuous an element in the Orcadian rocks. Furthermore, the sulphate of lime in its turn converted the vegetable matter into the bituminoids, which in a diffused form permeate—one might almost say saturate—so much of the Caithness Flagstones. I hold, therefore, that the exceptional durability of the Caithness Flagstones, which, of course, is caused by the large percentage of bituminous matter they contain, is due to the fact that conditions of inland drainage, one of the phases of desert conditions, prevailed during the Devonian period in the region where these occur.

*Desert Conditions during Torridonian Times.**—To my mind one of the most striking and significant illustrations of the principle upon which geologists interpret the records of the Past, by the study of the Present, is to be found in the Torridonian areas of the North-west of Scotland. If we review the conditions obtaining in the Sinaitic Peninsula [as was done with the aid of lantern slides on each occasion when this lecture was delivered], we find going on there to-day almost the exact counterpart of what must have taken place in pre-Cambrian times in Sutherland and Ross.

In Sinai, and probably also in Scotland, an area consisting of a gneissoid complex, exposed by upheaval and prolonged denudation, was subsequently covered unconformably by a series of derivative deposits. In the East this was the Nubian Sandstone; in Scotland it was some pre-Torridonian rock, whose general nature can be inferred only from the few pebbles derived from it which occur in conglomerates of later date. In both cases the areas were subsequently upheaved, and were afterwards exposed to subaërial denudation under humid conditions, whereby rivers excavated wide and deep valleys, cutting down through the overlying sedimentary deposits deep into the gneissoid masses beneath. Then

* As this idea of the desert origin of the Torridonian rocks has been put forward in the summer of 1897, as new, by another writer, the reader may be reminded that it has been taught in the author's geological classes in Edinburgh from 1895 onwards, and that it formed the principal theme of the public Address delivered by him in Edinburgh, on the 19th November, 1896.

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changed meteorological conditions set in; where previously rain had fallen, and rivers had excavated valleys, rain fell only occasionally, or only on those occasions when thunderstorms happened to burst over the regions in question. At all other times the arid conditions gave rise to great diurnal ranges of temperature. The rocks in consequence were heated soon after mid-day far above the temperature usual in more humid climates, and by early morning, owing to rapid radiation, had cooled down to the opposite extreme. In a rock composed of constituents of diverse mineral character, differential expansion took place, owing to their different co-efficients of expansion. The felspars in the rocks, instead of being slowly kaolinised by the action of rain-water charged with carbonic acid, gave way under the strain set up by extreme expansion and contraction, due to causes just mentioned. The ferro-magnesian minerals of the gneissoid rocks, having different co-efficients of expansion from that of the other constituents, in like manner splintered into fragments so small that they were easily blown away as dust by the wind. Little by little the rocks crumbled down, and the larger part of their wasted portions slid down the valley side as talus, to be eventually distributed and spread out in the bottoms of the wadys by the action of the occasional torrents arising during storms; the remainder, chiefly in the form of dust, was blown far and wide by the winds. Possibly in the case of the old Torridonian rocks these materials from the old gneissic mountains and their capping of sedimentary rocks may now and then have been distributed by the agency of lakes; but the agency of water there, as in Sinai, and in arid regions elsewhere, may have been chiefly limited to the distribution of the disintegrated materials by the action of torrents after the heavy rainfalls which occasionally deluge such regions.

In both these cases we have examples of the formation of arkoses, largely made up of the disintegrated materials of the gneiss, with the felspar fragments angular, bright on their cleavage-faces, and quite unweathered. The ferro-magnesian constituents in both cases seem to have been shattered to dust, and in that form to have been distributed far and wide by eolian agencies which winnowed the lighter from the heavier of the various minerals.

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In Sinai the disintegration will go on while the present arid conditions prevail, and until the wadys are filled with material to the level of the highest point whence their materials can be derived; then their formation must cease and their destruction commence.

In the case of the Torridonian rocks of Scotland, the old buried mountains, so well seen in the Loch Maree district and elsewhere, with their wadys levelled up to the brim, were afterwards lowered beneath the waves of the sea, and the whole accumulation was then planed off to a uniform level, upon which in later times, when further subsidence had taken place, the Lower Cambrian rocks were deposited.

The geological importance of the occurrence of desert conditions during Torridonian times has hardly, as yet, been estimated to its full extent. The special importance in this case arises primarily from the fact that the rocks in question consist of the materials of gneisses and granites reduced to a mechanical state of division without having lost their alkalies or other essential constituents. Agreeing in composition with some gneisses, they need but to be placed under suitable conditions for their re-conversion to come within the range at least of possibility. No one who is fully cognisant of the important changes which have been wrought upon the older rocks of Scotland since the Torridonian rocks were formed can have any doubt whatever that these rocks have almost certainly participated in those changes. It is well known that pyroxene-bearing rocks have been transmuted into amphibolites, these amphibolites into amphibolite schist, and this latter in its turn into biotite schist—under changes of one particular kind; while under changes of another kind, presumably under conditions of greater depth and pressure, similar rocks have first been rendered schistose, then, *if not annealed by subsequent contact metamorphism*, they have passed into the granulitic condition. With local and partial relief of pressure augen have then been developed. These augen in turn have aggregated into pegmatites, and finally, under suitable conditions of pressure and temperature, they may have returned entirely to the crystalline condition.

The same possibilities are open to the old desert-formed rocks of Torridonian age; their felspars have certainly passed into

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muscovite under dynamic metamorphism, thereby giving rise to muscovite schist. It is nearly certain that in other cases the alteration has proceeded further than this, and that these old arkoses have passed beyond the granulitic stage, and have altered at least in the direction of gneiss. Indeed, having regard to their chemical composition, there seems no valid reason why they should not, under suitable conditions, pass back into rocks of granitoid structure, if not actually into granite itself. Had the Torridonian rocks *decomposed* as they would have done under *pluvial* conditions, instead of *disintegrating*, as they did, under *arid* conditions, their alkalies would have been carried away in solution, and no such changes as those just referred to could have been within the range of possibility.

These British rocks, therefore, present us with records which, when interpreted by the light of modern geographical facts, can only be read as records of desert phases of geographical evolution. As such they appear to me to possess a high degree of interest, not only on account of the important geological and economic results to which they have given rise, but also because they bring prominently before our eyes the fact that each and all of the various phases of geographical evolution which are taking place upon even the remotest parts of the earth to-day have in the past, at one time or another, found a place in that part of the earth where now stand the British Isles.

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No. VII.—*Parka decipiens*, its Origin, Affinities, and Distribution. By J. Reid, W. Graham, and P. Macnair. With a Plate (No. VIII.), and a Section.

[Read 8th February, 1897.]

Since the publication of papers by Sir William Dawson and Professor Penhallow on *Parka decipiens*, renewed attention has been drawn to the origin and affinities of this deceiving fossil, and though the authors of the present paper had in their own minds been perfectly satisfied with the general conclusions arrived at by these writers, they are aware that doubts are still cast upon the propriety of associating certain stems and leaves with this organism as their fruit. Indeed, one eminent botanist, after all the evidence which has been produced, has been unable to accept it, and still expresses doubts of the vegetable origin of *Parka* at all.

It is principally, then, to meet such objections that the present writers have thought of bringing together, and re-stating, in the following paper, the whole argument in favour of the vegetable origin and rhizocarpian affinities of this remarkable fossil.

Parka decipiens was first discovered by Dr. Fleming, who described it in 1831.* It received its generic name from Parkhill, near Newburgh, on the Fife shore of the Firth of Tay, where Dr. Fleming had found it some two years previously in a bed of sandstone which underlies the Ochils, and stretches from Balmerino on the east to Abernethy and Dron on the west. Its specific name was given on account of its deceiving nature, a character which, as we shall see, it has since well maintained.

Hugh Miller, in his "Testimony of the Rocks," † quotes Fleming's description of *Parka*, as follows:—"These organisms occur in the form of circular flat patches, not equalling an inch in diameter, and composed of numerous smaller contiguous pieces. They are not unlike what might be expected to result from a compressed berry, such as the bramble or the rasp. As, however, they are found lying adjacent to the narrow leaves of gramineous [-looking] vegetables, and chiefly in clay slate, originally lacustrine silt, it is probable that they constituted

* *Cheek's Edinburgh Magazine*, 1831, p. 86.

† "Testimony of the Rocks," 1857, p. 443.

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the conglobate panicles of extinct species of the genus *Junicus* or *Sparzanium*."

Sir Charles Lyell, in 1855,* referred to the occurrence of *Parka* in the sandstones of Fifeshire and Forfarshire, mentioning its resemblance to the eggs of *Natica*, a gasteropodous mollusc, and also figuring a specimen of the latter to show the resemblance between the two forms. But he says that, as no gasteropodous shells have been detected in the same formation, the *Parka* has, probably, no connection with this class of organisms. He also cites Mantell's theory of their batrachian origin.

Hugh Miller, in 1857,† showed that the egg-theory of the origin of *Parka* had been first propounded by the quarrymen of Carmylie in Forfarshire, who likened it to "puddock [frog] spawn," an idea which was largely adopted by many of our leading geologists, but he himself favoured the vegetable origin, and compared it to a strawberry or raspberry. We may note here that the figures given in the "Testimony of the Rocks" show that peculiar radial structure which Prof. Penhallow believes to be characteristic of the sporocarp of a variety of *Parka*, to which he has given the name of *media*.

In the 7th edition of "The Old Red Sandstone," published after the author's death, as well as in some earlier issues, Hugh Miller describes ‡ the association of *Parka* with the remains of certain leaves and stems found in the quarries of Carmylie, as follows:—"irregularly grooved stems, branching out into boughs at acute angles, ... oblong leaf-like impressions too, and impressions of more slender form." It showed in particular, he says, "one large bunch of ribband-like leaflets, converging into a short stem, so that the whole resembled a scourge of cords."§ He then cites the views of Lyell that *Parka* was the eggs of some gasteropodous mollusc, and says further on—"It struck me as not very improbable that the reticulated markings of the flagstones of Carmylie may have been produced by the minute eggs of this fossil crustacean."

Rev. W. S. Symonds, who edited the 7th edition of "The Old Red Sandstone," added two notes, in which he favoured the vegetable

* "Manual of Elementary Geology," 1885, p. 421.

† "Testimony of the Rocks," 1857, p. 442.

‡ "The Old Red Sandstone," 7th ed., 1858, p. 164.

§ Referred to *Zosterophyllum* by Penhallow.

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origin of the organism. But, subsequently,* he returned to the crustacean derivation of *Parka*, and supposed it to be the egg-packets of *Pterygotus*.

Dr. Page, in 1856,† figured three specimens, two of them being *Parka*, and these he separately mentions as being respectively of vegetable, molluscan, and crustacean origin. But later he referred them to the spawn of *Eurypterus* and *Pterygotus*.

In 1864, Mr. J. Powrie‡ advocated the crustacean origin of the organism, and spoke of its association in certain of the Forfarshire beds with vegetable remains and with those of *Pterygotus*. "But," he says, "had the *Parka* been of vegetable origin the parent plant must have been rather highly organised, and, surely, had this been the case in a formation so well suited for preserving marks of structure, vestiges of a plant showing structure would ere now have turned up."

It thus seems that up to that time the tendency had still been to associate the affinities of *Parka* rather with the phanerogams than with the cryptogams, and this probably had something to do with the delay in accepting its vegetable origin.

Mr. C. W. Peach, in 1877,§ spoke of *Parka decipiens* as often found attached to stems of *Psilophyton*, and he further said, "these are, no doubt, the egg-packets of the large crustacea, *Pterygotus*, &c., found in the rocks there, and in other parts of Scotland."

Sir Archibald Geikie, in 1882,‖ described *Parka* as "clusters of crustacean egg-packets," while, in 1893,¶ he referred to the researches of Sir William Dawson and Prof. Penhallow upon this peculiar organism.**

* "Records of the Rocks," 1872, p. 209.

† "Advanced Text-book of Geology," 1st ed., 1856, p. 127.

‡ *Quarterly Journal of the Geological Society*, vol. xx., 1864, p. 416.

§ "Notes on the Fossil Plants found in the Old Red Sandstone of Shetland, &c.," *Transactions of the Edinburgh Geological Society*, vol. iii., 1880, p. 148.

‖ "Text-book of Geology," 1st ed., 1882, p. 714.

¶ *Op. cit.* 3rd ed., 1893, p. 793.

** Since this paper was written the subjoined footnote, referring to Dawson and Penhallow's views on *Parka decipiens*, has been published in Sir Archibald Geikie's "Ancient Volcanoes of Great Britain," 1897, vol. i., p. 287:—"An abundant organism in some of these deposits, named *Parka*, was first regarded as a plant, was afterwards believed to be the egg-packets of crustacea, and is now pronounced by competent authorities to belong to an aquatic plant with creeping stems, linear leaves, and sessile sporocarps."

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These last-named authors, in 1891,* gave the results of a detailed examination of *Parka decipiens* from specimens forwarded to them by writers of the present paper, and they undoubtedly established from a mass of evidence, not only the vegetable origin of *Parka*, but also its affinities to modern rhizocarpian forms. The following is the description of the genus:—"*Parka*, Fleming. Aquatic plants with creeping, rugose stems, linear leaves, and sessile sporocarps, bearing three kinds of sporangia. Sporangia 2 mm. in diameter, macrospores 40 μ, microspores 15 μ."

We now propose to bring before you the evidence upon which these conclusions have been arrived at by Sir William Dawson and Prof. Penhallow, as we believe that no detailed description of these later investigations into the nature and affinities of *Parka decipiens* has yet been given on this side of the Atlantic.

Mr. Robert Kidston, in 1893,† in a review of these authors' papers, and after describing the results they arrived at, makes the following remarks, which we quote here in their entirety, as they traverse the position we now propose to occupy:—

"The paper, which shows that a great deal of care and labour has been bestowed upon its preparation, must be carefully studied by all interested in the structure and affinities of *Parka*. But, on the showing of the writers themselves, there is scarcely enough of conclusive evidence—the most of the conclusions are really in the form of probable explanations or suggestions—to admit of the genus *Parka* being so fully and rigidly defined as has been done by Prof. Penhallow. As we have no evidence placed beyond reasonable doubt that the stems and leaves, with which *Parka* is associated, are really referable to it, the mere fact of their association on the same slabs cannot be accepted as proving any original organic connection between them. Their association may give ground for the assumption of their being different parts of the same organism, but in the absence of any certain knowledge of their organic union, one is scarcely justified in characterising a genus on merely supposed relationships. The evidence on which it is accepted that *Parka* possessed macrospores and microspores is far too slender to justify the important conclusion drawn from it."

* *Transactions of the Royal Society of Canada*, vol. ix., 1892, section 4, p. 3.

† *Annals of Scottish Natural History*, 1893, p. 254.

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One of the authors of the present paper, in a reply which was published in 1895,* made some remarks regarding Mr. Kidston's review of the original paper by Dawson and Penhallow, and showed that it is almost hopeless to look in the Old Red Sandstone of Scotland for plants having all their parts in organic union, also pointing out that Mr. Kidston himself on several occasions has broken the rule as regards this point. He further maintained that *Parka decipiens*, possessing sporocarps and sporangia of rhizocarpian structure, and being generally found associated with leaves and stems of rhizocarpian affinities, could afford to dispense with the necessity of finding them all in organic union.

To sum up. The true character of this interesting fossil appears to have been misunderstood for the following reasons. First,—the specimens of *Parka* usually met with, especially upon old surfaces of argillo-arenaceous rocks, are obscure and apt to serve for little more than to reflect the images of the ideas of each individual observer. Second,—Dr. Fleming, the discoverer of *Parka*, compared it with the fruit of phanerogams (*Junicus sparganium*), which was somewhat misleading. Third,—in recent years *Parka* has usually been regarded as the spawn of molluscs or crustaceans (probably *Pterygotus*). These conjectural opinions naturally directed the attention of geologists into such channels that the rhizocarpian origin of the plant was entirely overlooked. It was thus reserved for Sir William Dawson and Prof. Penhallow to place *Parka decipiens* upon a more scientific basis than it had previously occupied, and to establish beyond reasonable doubt that in it we have a plant possessing a creeping rhizome, linear subulate leaves, and a sporocarp with contained spores and prothalli. Such a plant undoubtedly finds its closest affinity with the recent genus *Pilularia*.†

Along the southern flanks of the Highlands, from Stonehaven on the east to the Firth of Clyde on the west, we find the Old Red Sandstone of Central Scotland thrown down by a powerful fault against the older crystalline rocks. Two of the present authors

* *Transactions of the Perthshire Society of Natural Science*, vol. ii., p. 123.

† Mr. Graham favours the opinion that while *Parka* belongs to the order Marsiliaceæ, it is the fruit of two species of that order, one like *Pilularia*, and another like *Marsilia*, the Australian Nardoo.

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have elsewhere given their opinion as to the relationships of this belt of Old Red Sandstone to the deposits seen at Lesmahagow and the Pentlands, on the one hand, and to those of Caithness and Orkney, on the other, and have shown that the Perthshire and Forfarshire beds must be referred to a middle group somewhat later in time than those of the Pentlands and Lesmahagow, and earlier than those of the northern area. But for details on this point the reader may be referred to the papers already published which bear on the subject.*

Parka decipiens is only to be found in certain beds of the Forfarshire and Fifeshire Old Red series, and is entirely absent from the lower group of that formation as seen at Lesmahagow, the Pentlands, and East Berwick. It is likewise non-existent in the upper group found in Caithness. Indeed, the only other locality in which we know of *Parka* occurring is in the Kidderminster beds of England. To those who would still maintain that *Parka* is the egg-packet of such a Eurypterid crustacean as *Pterygotus*, it may be pointed out that while the latter is known to occur in the upper Silurian rocks of Ludlow, Lesmahagow, and the Pentlands, and also in the Old Red Sandstone of East Berwick, and Caithness, not a vestige of *Parka* has yet been found in any of these rocks, a fact which we think is in itself highly presumptive evidence against any connection between the two organisms, especially when the great numbers of *Parka* in the Forfarshire localities are taken into account.

We may here note the bearing which the distribution of *Parka* has upon the question of the contemporaneity of the so-called basins of Lake Orcadie and Lake Caledonia, admitting at this point for the sake of argument that it was of vegetable origin and that it was swept into those lake-basins (whether marine or freshwater does not at present affect the main argument). We think it is difficult to see, if these so-called basins were strictly contemporaneous, how *Parka* should be so common in the one, and yet so entirely absent from the other. To this we propose to return again.

The following is the general structure and succession of the Old Red Sandstone rocks of Strathmore, and the position of the *Parka*-

* "On the physical conditions under which the Old Red Sandstone of Scotland was deposited. By Peter Macnair and James Reid." *Geological Magazine*, vol. iii., 1896, p. 106.

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bearing beds in them. Along the margin of the Perthshire and Forfarshire Highlands, and abutting against the older crystalline rocks, we find a massive series of conglomerates thrown down against the schists at high angles. These conglomerates, it must be borne in mind, do not represent the actual base of the Old Red series, but only the local base of a great series of rocks which evidently must have gradually overlapped each other as the land sank beneath the Old Red Sandstone sea. *Parka*, it has been stated, has been found in thin layers alternating with these basal conglomerates, and is referred to as occurring in this position in an editorial note appended to a paper by Hugh Mitchell upon these rocks which was published in the *Quarterly Journal* for 1861.* Proceeding next towards the south-east we find that the basal conglomerates pass into fine beds of shale and sandstone, which are bent into a synclinal trough. In the upper members of these sandstones there is a well-marked horizon, exposed along a line running from Rosemount near Blairgowrie by Murthly, Logiealmond, Callander, and Balmaha on the shores of Loch Lomond, where the strata are strongly charged with vegetable matter, principally the decorticated remains of *Psilophyton* and *Arthrostigma*. The geological position of this well-marked zone of plant-remains towards the west in the counties of Perth, Stirling, and Dumbarton, was indicated in a paper by Messrs. R. L. Jack and R. Etheridge, junr., in 1877.† To show the exact geological position of these beds the authors describe a section from the heads of the Keltie and Ruchill Waters, through Uamh Mhor and Uamh Bheag, to Sheriffmuir. The whole section forms a deep synclinal trough whose northern limb, seen in the Keltie and Ruchill Waters, consists of massive beds of conglomerate, with shales and interbedded andesites lying in an almost vertical position against the crystalline rocks of the Highlands. These conglomerates, near the summit of this synclinal trough, pass upwards into the axial beds of Uamh Mhor, a series of greenish-grey flags and thin-bedded flagstones, plentifully charged with plant-remains which belong principally to the genera *Psilophyton* and *Arthrostigma*. From this point towards Sheriffmuir the series is a descending one, forming the southern limb of the syncline

* *Quart. Jour. Geol. Soc.*, vol. xvii., 1861, p. 148.

† *Quart. Jour. Geol. Soc.*, vol. xxxiii., 1877, p. 214.

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and repeating the former beds again in a finer condition, the whole ultimately passing downwards into the volcanic zone of the Ochils. Traced south-westwards into the low ground on the west side of the Teith, the flagstones with their plant-remains are exposed at the surface, the higher axial beds of Uamh Mhor having been entirely stripped away by denudation. Further westward towards the shores of Loch Lomond the area occupied by the Lower Old Red Sandstone becomes narrowed down, owing to the faulting against it of the Upper Old Red towards the south. Still the flagstones with their plant-remains are exposed right on to the shores of Loch Lomond and the Firth of Clyde.

Returning now to the beds in the East of Scotland, it will be seen that, so far as these upper beds characterised by *Psilophyton* and *Arthrostigma* are concerned, they appear to represent a well-marked, and distinct horizon, near the summit of the Old Red Sandstone Series, as seen in Central Scotland. On crossing the volcanic zone of the Sidlaws into the Carse of Gowrie we find a series of sandstones coming up from underneath that range of hills, as at Balruddery, and which rolling over dip beneath the Ochils on the other side of the Firth of Tay. In these sandstones we find *Parka decipiens* associated with *Pterygotus*, *Cephalaspis*, &c. Traced north-eastwards into Forfarshire we find *Parka* in great numbers at Myreton, Carmylie, Turin Hill, Glammis, and other localities.

In the accompanying section we have shown the relative position of the *Parka* and *Psilophyton* beds of the Old Red Sandstone of Central Scotland along a line drawn from the base of the Grampians through Blairgowrie and Rosemount, and from thence across the Sidlaws to Balruddery in the Carse of Gowrie, terminating on the other side of the Firth of Tay at Parkhill and the Ochils. Against the crystalline rocks (A) of the Highland border we find the basal conglomerates (B) with their interbedded volcanic rocks thrown down into an almost vertical position by a powerful fault. Near Blairgowrie these basal conglomerates are cut off by a second fault, with a down-throw to the south which ushers in the higher members of the series in an almost horizontal position; these latter consisting of red and grey sandstones (C) with local beds of conglomerate, which, at Rosemount, about two miles to the south of Blairgowrie, are abundantly charged with

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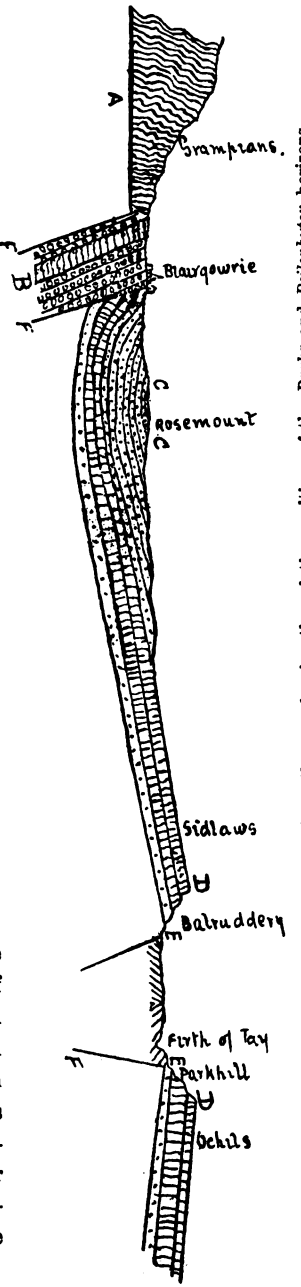
plant-remains referable to *Psilophyton* and *Arthrostigma.* The section is a descending one from this point towards the volcanic zone of the Sidlaws (D), and after crossing it near the exposed base of the volcanic zone into the Carse of Gowrie, we come upon the *Parka* beds (E) at Balruddery, which again roll over to form the Ochils on the south side of the Firth of Tay.

It seems to us then that we have in the *Parka* and *Zosterophyllum* zone of Fifeshire and Forfarshire, and the *Psilophyton* and *Arthrostigma* zone of Perthshire, Stirlingshire and Dumbartonshire, two distinct and well-marked horizons of plant-remains, of which the former, occurring near the base of the volcanic rocks of Perthshire and Forfarshire and found associated with their characteristic fish and crustacean remains, is undoubtedly the lower of the two. The latter zone occupies a much higher position in the series, being found far above the top of the volcanic zone, and amongst the highest beds exposed in the synclinal trough of Strathmore.

The bearing which the existence of those two well-marked horizons of plant-remains has upon the question of the contemporaneity of the Old Red Sandstone deposits to the north and south of the Grampians, seems to us to be even of greater importance than that derived from their fish and crustacean remains, notwithstanding the fact that so little



Section across the Old Red Sandstone of Strathmore, showing the relative positions of the *Parka* and *Psilophyton* horizons.

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reliance has hitherto been placed upon the evidence derived from the occurrence of the plants. That the value of this evidence is not over-estimated must be conceded, if we consider for a moment the physical conditions then existing, as implied by the contemporaneous lake theory. According to this we have two lakes existing during the same period of time, and separated by a common land-barrier, which could have only been a few miles wide during their maximum extension. We would naturally expect that under such conditions the vegetable remains found in each basin would be more or less similar, and especially in the case of the land-plants, yet this is by no means the case. In Central Scotland we have those two well-marked horizons of plant-remains, the one characterised by *Parka* and *Zosterophyllum*, the other by *Psilophyton* and *Arthrostigma*, and though both *Psilophyton* and *Zosterophyllum* are known to range upwards into the Caithness beds, yet this is not of much significance when we remember that *Psilophyton* occurs in the lower, middle, and upper sandstones of Gaspé and New Brunswick. It is more especially when we come to consider the striking discrepancy which exists between the plants found in the Caithness area, and that of Central Scotland, that the theory of two contiguous and contemporaneous basins becomes wholly untenable. As we have already remarked, the occurrence of *Parka decipiens* alone in such a well-marked zone of rocks, and in such profuse numbers in the area south of the Grampians, without a vestige of it being found in the northern area, is of itself sufficient evidence to warrant our looking with grave suspicion upon any such theory. But when we find that such land-plants as *Lycopodites*, *Calamites*, *Lepidodendron*, &c., are found in the northern area, but not in the southern one, while *Arthrostigma* is found in the latter, but not in the former, any theory which makes those two deposits contemporaneous and demands for them a common land-barrier is, in our opinion, wholly unscientific and untenable.

The rocks which hold *Parka* are mostly of an argillo-arenaceous character, and the organism has either been replaced by black, carbonaceous material, or by pseudomorphs of iron. In the latter form no structure whatever can be traced, and the plant often appears as mere blotches of red oxide of iron which can only be

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referred to *Parka* by their shape and by the occasional faint impression of the discs.

In this black, carbonaceous replacement the structure of *Parka* has been best preserved, and there not only the form, but the minute microscopical details, may be also found. The specimens in this condition are mostly obtained from Myreton. We have previously noted the fragmentary state of the plants found occurring on the same slabs with *Parka*, and the berry-like bodies to which the term *Parka decipiens* was originally given occur in an equally fragmentary condition, though they may not uncommonly be found almost perfect in their oval or circular form, and showing distinct traces of an indusium. These bodies, however, have never been found in undoubted organic union with any of the other vegetable remains, though probably many hundreds of them may have been observed in the course of the last sixty years. So universal is this isolation, that some observers have contended that *Parka decipiens* is itself a complete vegetable, though they have not shown us its affinities. Evidence is not, however, awanting of it having been attached to a stalk, as, for instance, in the specimen from Lord Kinnaird's Collection, figured in Hugh Miller's "Old Red Sandstone," and in certain specimens exhibited by the authors.

We cannot, however, feel ourselves justified in ascribing to *Parka* any such vegetable origin as has no support from living forms, or, at least, not until we have exhausted all the known forms of plants, and in the concluding part of this paper we shall attempt to show that in those fragmentary leaves and stems found associated with *Parka* we have the representatives of the rhizome and foliage of a plant of which this organism is the fruit, and which has its nearest allies in the recent Rhizocarpeæ, the leading features in the structure of which we may here briefly recapitulate.

The vascular cryptogams have been divided into two groups—the heterosporous and isosporous—according as they possess one or two kinds of spores, the former having been sub-divided into the two classes Rhizocarpeæ and Selaginellaceæ. It is the Rhizocarpeæ to which we would refer *Parka* as being most nearly allied, and they receive their name from the fact that their organs of reproduction are produced near the base of the leaves or on the rhizome. They grow submerged in, or floating upon, water;

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the spores are of two kinds—the macrospores and microspores; and the prothalli are small and project slightly from the spores. They have been divided into two families, the Salviniaceæ and Marsiliaceæ. In *Salvinia natans* the roots are entirely wanting, the leaves being frondose or more or less pinnate in their arrangement. The sporangia are produced in unilocular sporocarps, the latter being formed two together, or in large numbers on the teeth of submerged leaves. *Marsilia* is possessed of a rhizome which creeps along the bottom of the water, and bears cuneate leaves in a whorl upon a long stalk, the under-surface of the stem bearing roots, and the sporocarp is somewhat of the shape of a bean set upon a pedicel. In *Pilularia* we have, as in *Marsilia*, the long creeping stem, but the leaves are different, being of a simple linear subulate form. Its sporocarp is globose in shape and set on a short stalk, and internally it shows a quadrate structure, being divided into four chambers. Goebel* says, "Each chamber has on the side towards the wall of the capsule a cushion-like placenta which ascends from below through the length of the chamber, and has a vascular bundle behind it. On this placenta are placed the stalked sporangia forming a sorus, which has macrosporangia chiefly at its lower end, and only microsporangia above."

In "Notes on Specimens from the Collection of Messrs. Reid and Graham," by Dawson and Penhallow,† it is stated that:—"The *Parka decipiens* usually consists of oval masses bearing rounded impressions of disc-like bodies of carbonaceous matter; associated with these are also stems and linear leaves of two dimensions. The authors show that the fossil is probably a rhizocarp allied to *Pilularia*, and that there are three forms recognisable, of which one is referred to the species, and the other to the varieties. The views thus stated are based upon differences of size, and upon the fact that certain of the disc-like bodies show spores of two kinds, and in some cases prothalli in various stages of development, all derived from the same sporocarp."

The sporocarp of this plant is of special importance, constituting,

* "Outlines of Classification and Special Morphology of Plants," by Dr. K. Goebel, 1887, p. 240.

† *Nature*, April 10, 1890.

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as it does, the fossil to which the attention of geologists has been directed for the last sixty years. It shows the internal grooving possessed by that of the rhizocarps. It occurs in three forms, *Parka decipiens*, *P. media*, and *P. minor*, their dimensions being respectively 3·5 × 5·5 cm., 13 × 20 mm., and 6 × 16 mm. The stems of *P. decipiens* are somewhat large and of a rugose character, the leaves being 1 cm. broad, with rounded terminations. The stems of *P. media* and *P. minor* are of a smaller size, and the leaves measure about 2 mm. in breadth, closely resembling the rachis of *Pilularia*. One of our specimens from the flags of Turin Hill distinctly shows a number of stumps of leaves proceeding from a creeping rhizome.

It might be argued that the sporangia of *Parka* represent individual sporocarps attached to an oval, striated, leaf-like body. This view, however, is rendered untenable by one or two discoveries made by us in the shales of Myreton. On opening some shales we found *Parka* in two parts, one the usual cluster of discs, the other their impressions. From this we conclude that the hexagonal and rounded forms of *Parka* devoid of discs (in some cases at least) represent its covering, the grooved portion of the sporocarp forming one side, this covering the other, thus completing the indusium or sporocarp (see Plate VIII., fig. 10).

In a recent review of Dawson and Penhallow's paper on *Parka*,* which we have already cited, Mr. Kidston remarks, "But in the absence of any knowledge of their organic union, ... we have no evidence placed beyond reasonable doubt that the stems and leaves with which *Parka* is associated really belong to it."† We frankly own that this botanical rule is a perfect one, but in geological formations the plant-remains are obscure and fragmentary, and palæo-botanists generally are found breaking rules of so strict a kind. We would again point out that we have examples of this in papers by Mr. Kidston himself. In one on the occurrence of *Arthrostigma gracile* in the Old Red Sandstone of Perthshire,‡ he states that the Perthshire specimens must be identified as *Arthrostigma gracile* (Dawson), though the

* *Trans. Royal Soc. of Canada*, 1891.
† *Annals Scot. Nat. Hist.*, 1893, p. 254.
‡ *Trans. Royal Phys. Soc.*, Edin., 1893.

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evidence upon which this opinion is based is comprised in a few fragments of somewhat obscure stems devoid of branches or fruit. Again, in a paper "On the occurrence of *Equisetum* in the Yorkshire coal measures,"* this author figures a representative cone 1 inch in length by $\frac{6}{10}$ inch in breadth, and states that beyond evidence gained from an examination of the surface of the fossil (cone or cones) there is none, neither stems, branches, nor fruit occurring in the Carboniferous formation of England.

We think these examples show that, however perfect the rule of organic union of stem, branch, and fruit may be in theory, it is not quite applicable to plant-remains from geological formations. *Parka* perhaps occupies a stronger position than either of these examples just quoted, for our Turin Hill specimen shows rhizome and leaves undoubtedly united, while specimens of sessile and stalked fruit are not uncommon. It seems not improbable, then, that in *Parka decipiens* we have a somewhat generalised plant, shadowing forth the recent rhizocarps (*Pilularia*, *Marsilia*, &c.), though of a larger form.

Before considering the microscopic structure of the *Parka* discs, let us briefly indicate the methods adopted in preparing these bodies for microscopic examination. In the Myreton specimens, the sporocarps are, as already noted, generally replaced by carbonaceous matter, the individual sporangia of which can be easily detached. Placing some of the discs in a test-tube with nitric acid it is then held over a flame and boiled out. In the majority of cases the discs are scarcely touched by this process, but from a few the carbonaceous coating is removed, and an inner amber-coloured layer revealed.

Viewed microscopically even as opaque objects without being treated with nitric acid (though its action tends to make it more distinct) a marked hexagonal reticulation of the surface of the sporangia may be observed. Sir William Dawson compares this structure to similar ones seen in *Protosalvinia* of Brazil and Ohio, and to the hexagonal areolation seen in the living rhizocarp *Salvinia*. He further observes, "This was so far an indication of vegetable affinity, as I know of no crustacean or molluscan ova showing such cellular areolation."

Amongst the discs, which, by the boiling process, have become

* *Annals and Mag. Nat. Hist.*, 1892, pp. 140, 141.

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more or less transparent, we may, in the first instance, note those which show a distinct cellular wall-structure. This we have not found by any means common; in fact, most of the discs when examined in their unbroken state show no structure whatever. Sir William Dawson and Prof. Penhallow both point out the existence of this structure, and we may quote the latter writer's words.* "Internal to this, however (that is, internal to the outside black, carbonaceous layer), the disc was observed to consist of a distinct tissue composed of rather thin-walled cells, thus giving direct proof that they were not simple spores, but of the nature of sporangia." We also, with Prof. Penhallow, have observed what seem to be macrospores in the yet unbroken disc, and have no doubt that they are similar in origin to those bodies which we shall presently describe.

The next process in the examination of the discs is that of breaking them up in water, when the yellow-amber-like under-layer is seen to resolve itself into irregular masses, and also (when carefully examined) into numbers of minute oval bodies, which Prof. Penhallow considers to be analogous in every respect to the macrospores of our living Rhizocarpeæ. These are generally translucent, but vary more or less according to the effect of the nitric acid upon them. In most cases the remains of an outer cell-wall is still visible in the darker carbonaceous portions seen adhering to the macrospore. Prof. Penhallow has examined a large number of these bodies and finds their average size to be about 34 μ., while if their original carbonaceous investment were replaced they would then be about 40 μ. We have measured several and can confirm this estimate of their average size, though there seems to be a considerable variation. In comparison with the spores of recent forms Prof. Penhallow shows them to be much larger than the microspores of *Selaginella*, and about the same size as the spores of *Lycopodium*, but in some instances we have seen, with more or less of the carbonaceous envelope still adhering, they appeared to be much larger than those of *Lycopodium*.

Sir William Dawson notes the occurrence of the triangular mark of *Isoetes* on some of the spores. We have not yet observed

* "*Parka decipiens*," in *Trans. Roy. Soc. of Canada*, vol. ix., sec. iv., 1892, p. 14.

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this, but a distinct rectangular marking which may have had the same origin undoubtedly exists in several of the spores seen in our slides. We have also found in our preparations of the discs, the smaller forms estimated by Prof. Penhallow to measure 15 μ. in diameter, and referred to by him as microspores, these two bodies having been produced from the same sporocarp, and thus being allied to *Marsilia* and *Pilularia.*

The next most important feature is the aggregation of cells often seen in the unbroken sporangia, and which Prof. Penhallow believes to be the remains of prothalli. These generally show a central carbonised mass, surrounded by a series of cells of variable dimensions, with a more or less radial arrangement. They are quite distinct from the macrospores or microspores before mentioned, both in shape and in size. He figures a series of these aggregations of cells, and has arrived at the conclusion that they are prothalli in different stages of development, a view which, he says, is well supported by their form and structure.

Another structure which we have seen in certain of our slides, but which is not recorded by Sir William Dawson or Prof. Penhallow, is the existence of spiral or scalariform tissue in certain of the broken-up discs. It is admittedly difficult to conceive of such a tissue existing in the sporocarp or sporangia, and it may possibly simply represent part of the stems or leaves. Goebel, however, refers to the existence of a vascular tissue in the sporocarp of *Pilularia,* to which we have already referred.

Having thus summarised the most recent scientific opinion in regard to *Parka,* and having adduced our own evidence, we now think it remains for those who still question its vegetable origin to express something more than a negative opinion, or, in a word, to give us some direct evidence as to what genus the foliage found associated with *Parka* really belongs. It will be generally admitted that Sir William Dawson and Prof. Penhallow have placed, for the first time, the *Parka* question upon a scientific basis, so that no longer a conjectural opinion is applicable to it, and any further inquiry upon the subject, to be of the slightest scientific value, must follow upon the same modern lines of research.

In conclusion, we would remark that *Parka,* after sixty years'

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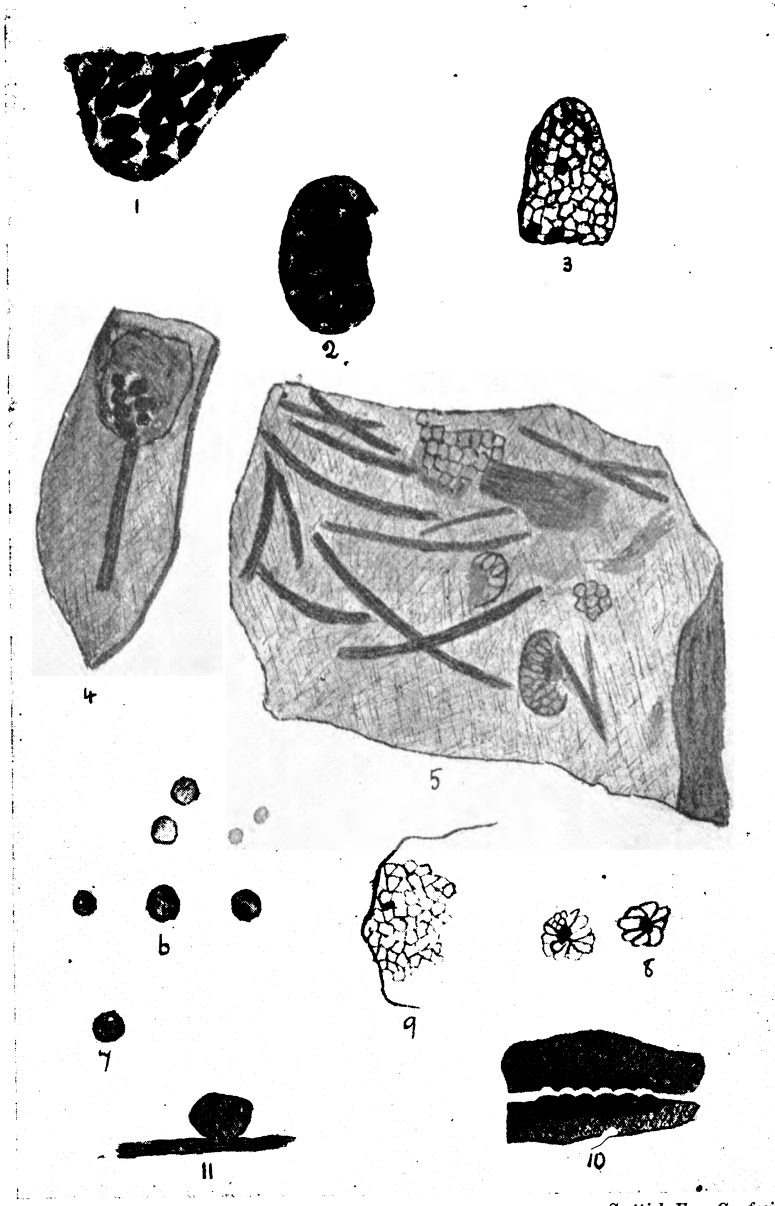

P. Macnair delt. *Scottish Eng. Co. fecit.*

PARKA DECIPIENS, FLEMING.

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controversy, has at last been definitely proved to be of vegetable origin, and that in its creeping stems, subulate leaves, sporocarp spores, and prothalli, it, in our view, presents a close affinity to the Rhizocarpeæ.

EXPLANATION OF PLATE VIII.

PARKA DECIPIENS.

Fig. 1.—*Parka decipiens, Flem.*, part of sporocarp, showing sporangia, x 3.

Fig. 2.—*Parka minor, Pen.*, showing radial arrangement of sporangia in sporocarp, x 2.

Fig. 3.—*Parka media, Pen.*, sporocarp, natural size.

Fig. 4.—*Parka media, Pen.*, showing supposed case of stalk attachment, natural size.

Fig. 5.—Slab with fragments of sporocarps of *Parka* and broken leaves of *Parka* and *Zosterophyllum*, natural size.

Fig. 6.—Group of macrospores and microspores, x 150.

Fig. 7.—Spore with rectangular marking, x 150.

Fig. 8.—Prothalli, from unbroken sporangia, x 150.

Fig. 9.—Hexagonal areolation on surface of sporangia after treatment with nitric acid, x 50.

Fig. 10.—Specimen showing sporocarp of *Parka* in section, and split along upper and under surface. This proves sporangia to have been enclosed in an indusium.

Fig. 11.—*Parka minor, Pen.*, showing supposed case of sessile attachment, natural size.

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No. VIII.—On a Section of Carboniferous Strata in a Cutting of the Caledonian Railway at Lissens, Three Miles North-east of Kilwinning, Ayrshire. By John Smith. With two Sections.

[Read 12th December, 1895.]

This section, which was made during the construction of the Caledonian Railway to Ardrossan in 1887, is one of much interest, and as the strata are principally beds of compact sandstone, their exposed surfaces are still fresh enough to repay examination. Rather more than a mile north from the north end of the section the lower limestones crop out, and have been worked for many years, at the Auchenmade quarry, near by. About as far south from the south end of the section the Highfield limestone was at one time worked, as, to a small extent, it is still, at Gowkha sandstone quarry, where the "tir" * is being stripped off the rock.

The Lissens strata occupy a position intermediate between those two series of limestones, and consequently correspond to that of the coal measure series of the Dalry district. The section is 930 yards long, and the railway gradient through it is 1 in 70, the incline being towards the south-west. The greater part of this length is taken up by a large syncline which is cut up by nine small faults. Towards the south-west part there is a small anticline followed by a syncline with one fault. The whole extent of the section is covered by Boulder-clay measuring from 2 to 9 feet thick. Where thickest it is of a bluish colour in the lower part, the upper part being rusty-coloured from weathering.

Beginning with the lowest beds (geologically speaking), at the north end of the cutting, we find thin sandstone plies (with minute mica scales), about 5 feet thick, and lying in a nearly horizontal position. Over this is a bed of sandstone of 2½ feet, at first nearly level, but further on dipping south-west. It is yellowish in colour, fine-grained towards the bottom, and coarse above, its surface having been ironstained since the cutting was made. From this the beds all dip south-west, till, at the lowest part, they are level for a short distance. Above the sandstone are 10 feet of shale, and sandstone plies with fine mica, while

* "Tir" is the Gaelic word for country, whence soil or earth. Quarrymen use it to denote the material removed from above a post of rock.

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through the beds are here and there to be seen the long, compressed roots of *Stigmaria ficoides*. Next is dark shale about 3 feet, and over it 8 feet of sandstone, penetrated from top to bottom by fine plant-roots. Above this is a thin dross coal of 6 to 9 inches, overlaid by 5 to 6 feet of greyish volcanic ash with an irregular surface (fig. 1). This ash has not burnt the coal in

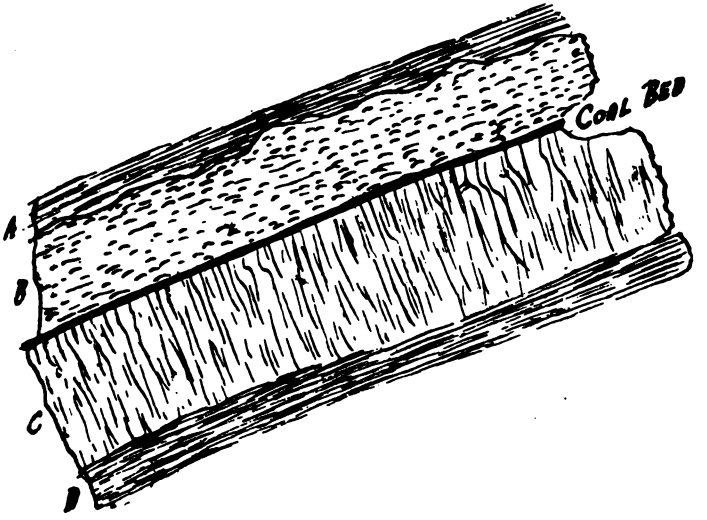

Fig. 1.—*A*. Shale. *B*. Volcanic Ash, 5 to 6 feet thick, resting on Coal-bed. *C*. Sandstone, 8 feet thick, with plant-roots from top to bottom. *D*. Shale.

the least, and through it are irony bands and nodules, with, at parts, a thin band of blackband ironstone above the coal. Above the ash is a bed of dark shale from 3 to 6 feet thick, containing a few ironstone nodules. Since the cutting was made this shale has weathered considerably, not into clay, but into small granular particles, a characteristic feature of weathered shale containing finely divided vegetable matter. Above this are 4 feet 4 inches of bedded sandstone, now ironstained on its surface, and having irony nodules in its middle part.

This sandstone is seen to begin, on the east side of the cutting, as a thin wedge, and at 50 yards further on, when 6 feet thick, it dips under the level of the line. Then come 20 inches of light fireclay with plant-roots and large nodules of clay ironstone, and above that 3 inches of coal. A light-coloured fireclay of 2½ feet

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brings us to another 3-inch coal, overlaid by 4 feet of "lithy" sandstone with an ironstained surface and the upper part containing fine plant-roots. Above this lies dark shale with non-septarian ironstone nodules, followed by a coal of 6 inches, overlaid by sandstone.

In this position there is a "white horse" whin, 18 inches thick, on the east side of the railway, extending for 41 yards, and dying away in the shale as a long thin white tongue.

We have now reached the first fault—a small one—with about 3 feet of throw. Abutting against the overhanging "vees" of the fault on its south-west side are the following—a thin shale, a 7-inch coal, 4 feet of sandstone with plant-roots, 3 feet of dark shale with non-septarian ironstone nodules, a 6-inch coal, and 6 feet of strong sandstone with fine rootlets in the upper part. Above this sandstone is a 9-inch coal-bed, and overlying it 5 to 6 feet of "lithy" sandstone, very hard in the upper part, and containing irony nodules. Then comes a dark 3-feet shale, with clay ironstone nodules, and above it a 6-inch coal, overlaid by a bed of sandstone.

The last four beds abut against a fault, just about the bottom of the syncline, and the inclination of the strata now begins to rise to the south-west.

Reading downwards, there lie, on the south-west side of this fault, part of a sandstone bed, an 11-inch coal-bed, a shale-bed of 3 feet, and a bed of sandstone of from 3 to 4½ feet, very strongly current-bedded in its lower part. The current-bedding dips to the north-west. Below this sandstone is a 12-inch coal-bed with a thin "daugh" parting, and a thin clay-bed on top. Below the coal is a dark shale-bed of from 3½ to 4½ feet, with clay ironstone nodules, and under it 2 to 3 feet of white sandstone resting on two coal-beds, each of 13 inches, with a thin parting of shale. The shales, sandstones and coals abut on a fault, between which and another fault 17 yards south-west of it are dark shale, sandstone, dark shale, light shale, and sandstone.

Against the south-west side of the last-named fault are thin sandstone plies of about 3 feet, sandstone in two beds ironstained by weathering of 2 to 4 feet, coal 9 inches, blackband ironstone 2 inches, irony shale 1 to 2 feet, grey volcanic ash with irony nodules (in this ash-bed I got a plant showing fine remains of

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structure), and shale 18 inches. These beds are roughly horizontal for the most part, but towards their south-east end they rise steeply towards a fault. Under the bedded sandstone there is shale, with three beds of "white horse" whin, which may be seen just rising in the bottom of the cutting.

Within a space of 14 yards there are (including the last-mentioned one) four faults with beds of shale and sandstone between each, and between two of them one of the "white horse" whin beds already spoken of (fig. 2, C, D, E.). Between this

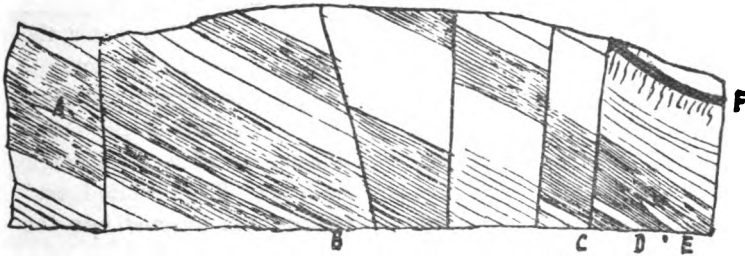

Fig. 2.—*A, B, C, D, E.* Beds of White Trap in Shale. *F.* Coal-bed resting on Sandstone. This section is cut up by 5 Faults.

fault and another 30 yards further south-west there are, reading downwards, sandstone, shale, sandstone, sandy plies, shale with thin lenticular bands of clay ironstone, "white horse" whin (18 inches with vertical joints every few inches and pin-head nodules of carbonate of iron). This whin has slightly indurated the shale for a few inches both above and below it, showing that it is an injected bed. By exposure its surface has become of a colour approaching burnt sienna, but its top, which is very smooth, has not been altered in colour and is whiter than a freshly-fractured surface. A band in its centre about 7 inches broad is mouldering away from the influence of the weather. It is cut off by the fault, which shows that the latter was formed subsequently to the injection of the whin, and the same may be said of one of the "white horse" beds. Under the latter are shale, with lenticular clayband ironstone, and sandstone. South-west of the fault, reading downwards, are sandstone and shale, with a small tongue of "white horse" abutting on the fault and dying out in the shale at a short distance (see fig. 2, A). Under the shale are 7½ feet of bedded sandstone, four of the beds being strongly ripple-marked, with the long direction of the ripples extending (roughly)

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north and south, which shows that when they were formed either easterly or westerly winds were prevailing. Under the sandstone are a few feet of dark sandy plies, which, with part of the bed above them, form a small anticline. The sandstone bed abuts on a fault lying in the bottom of a syncline, and on its south-west side, reading downwards, are sandy plies, shale, sandstone with glassy slickensides, and dark sandy plies with irony nodules and worm-tracks. This completes the section.

From the nature of the principal materials of which they have been built up—sandstone, shale, and coal—the strata composing this section have evidently been laid down in shallow water, the coal being formed from vegetation grown on the spot. The volcanic ash, though it occurs twice in the section, is apparently the same bed, and possibly the tail end of one of the beds of the Dalry district, three miles distant, where ash-beds of a considerable thickness in the same relative position occur. The "white horse" whin has evidently, as already mentioned, been injected into the strata before the faulting took place, as at two places it is seen to be "thrown" by the faults. Three of the coal-beds are seen to be resting on sandstone, and nine of them are overlaid by it, one by volcanic ash, and two by shale. Perhaps none of the strata are of marine origin, at least no marine fossils have been found in any part of the section.

Because three of the coal-beds in this section are seen to rest directly on sandstone without the intervention of underlying clay, it might be argued that these beds had been formed by drifted vegetation, but the abundance of plant-roots in the sandstones shows that the coal-beds have evidently been accumulated from the remains of local plant-life.

At no part of the beds are stems of trees or shrubs to be seen in an erect position in the ash, but one of my microscopic sections of it shows a number of minute plant-remains, the cell-structure of which is beautifully preserved.

Under some of the coal-beds there is a thin, soft, black parting composed mostly of coal. When this material is washed, and examined microscopically, a number of *triletes* or lycopodaceous spores may be detected. They are generally pressed quite flat, and are oval in shape, some of the species being smooth or granular, and others ornamented by prominent roundish tubercles and spines.

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Looking at the comparative evenness of the surface of the ground at this place, one would scarcely think there were so many "troubles" and "ups and downs" in the strata as this comparatively short section of the lower coal measures of Ayrshire shows to exist.

For the convenience of those members who may wish to visit this very interesting exposure of beds, I may state that it is just about a mile south-west of the Auchenmade station of the Caledonian Railway to Ardrossan, which is also conveniently situated for the geologist who wishes to visit the fine fossiliferous quarries of Auchenmade, as well as those of Bowertrapping and Auchenskeith, besides the interesting sections of limestone, shale, and volcanic ash, exposed in the Cleaves Cove Glen, near Dalry.

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No. IX.—On a Globular Structure in a Patch of Shale enclosed in the "Deil's Dyke," near Greenan Castle, Ayrshire. By John Smith. With a Diagram.

[Read 12th November, 1895.]

From the Doon Water to beyond the Heads of Ayr there are seen a number of trap dykes—at least twelve—all running in a north-west and south-east direction, some of them being well-exposed on the shore and in the sea-cliffs. They probably belong to the Tertiary period, and cut through the cement-stone, volcanic tuff, calciferous sandstone and porphyrite. The "Deil's Dyke" is perhaps one of the most conspicuous, and is placed just a short way south-west of the ruins of Greenan Castle. The tide sweeps over a large part of the dyke, till at about high-water mark, where it rises abruptly from the shore.

Here, on its north-east side, a patch of light-coloured shale, which has been entangled in it, can be examined. At this point the dyke is 18 yards across, is roughly columnar, and is divided by perpendicular longitudinal cracks. The patch of shale is seen at 8 yards from its north-east edge, and measures about 18 yards long by 3 feet thick, and 9 feet high above where it shows clear of the volcanic rock, into which its south-east end without doubt penetrates some distance. It is evidently a detached part of the cement-stone series, and lying almost horizontally in the dyke, on both sides of which it can be examined.

A section of this patch of shale, in descending order, is as follows:—

1. A band which has not assumed the globular structure.
2. A 22-inches band with large globules, some joined together.
3. An 11-inches band free from globules.
4. A 7-inches band with globules.
5. Several thin bands with a few globes.

The larger globes are over half an inch in diameter, and the smaller ones little bigger than a full stop in this page, some being perfect spheres, and others very irregular in shape. When the surface is weathered they stand out boldly, but do not show in a fracture, although an occasional sphere may appear *in relief* on the face.

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The shale when polished shows the globes with a dark centre, surrounded by a band lighter-coloured than the matrix, and sharply defined on the outside rim, but gradually shading away into the dark centre. The light-coloured ring weathers more readily than either the dark interior or the mass of the shale, and the warts seen *in relief* on weathered surfaces are just the dark centres of the globes.

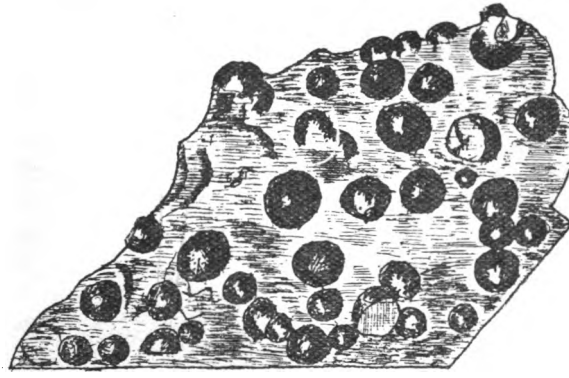

Fig. 3.—Weathered Surface of a Fragment of the Shale enclosed in the "Deil's Dyke."

The sections of the cement-stone series exposed on the shore are an alternation of light-coloured shales, thin bands of fine-grained impure limestones, and occasional beds of fakes. In the patch of shale enclosed in the "Deil's Dyke" there appears to be none of the fakes, and probably none of the limestone, at least the rock does not effervesce with acid. There can be no doubt that this globular structure has been developed by the heat from the dyke, but in what manner is for chemists to explain.

Bits of shale in similar positions are usually porcelainized, or converted into a rock of flinty hardness, but this patch is so soft as to be easily cut with a knife.

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No. X.—"Coal Apples" from Lugton Water. By John Smith. With a Diagram.

[Read 12th November, 1895.]

Near Mavisbank on the Lugton Water there is an outcropping thin seam of coal, the position of which is a few fathoms under the Highfield limestone. This coal, originally a kind of inferior gas-coal, has been pretty much altered by the influence of an intrusive sheet of trap, which, though not touching it at this point but lying some distance below it, has apparently been the cause of it having lost its volatile matter. Instead of taking a columnar structure, however, which is a common feature in altered coals, it has assumed a sort of globular form, the "globes" not being perfect spheres, but resembling somewhat the shape of a kidney potato. These vary in size from about 1 inch to over 3 inches, and have several outside coatings which can be easily peeled off. Sometimes their surfaces show considerable depressions, each "coal apple" being contained in a semi-cubical piece of the mineral. In the process of extraction many of them split along the original bedding-planes, but always in the direction of their long axes.

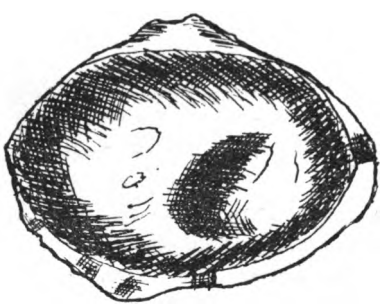

Fig. 4.—"Coal Apple" from Lugton Water.

The reason why the coal assumed this semi-globular structure has probably, in the instances above noted, been owing to the proximity of the trap, which has caused a softening of the mineral, and has allowed the particles of the coal freedom of motion, resulting in their taking up new positions. I have, however, seen "coal apples" from a free coal, which did not show signs of ever having been affected by heat.

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No. XI.—"Shale Sockets" of Cement Nodules from Thornliebank. By John Smith. With a Diagram.

[Read 12th November, 1895.]

Many of the members are doubtless aware that in 1894 a quantity of shale rich in fossils was removed from the foundation of a gasometer in Thornliebank print-works, and deposited in the old Arden limestone workings. This shale contains many cement-stone nodules, and in connection with them occur the peculiar "sockets" which I am about to describe. In their original position each nodule has two of these, one above and one below, the hollows or cups of the "sockets" assuming the shape of the parts of the nodules which fit into them. But they are only present where the nodules are globular or semi-globular. In shape they are like little shallow saucers, or they may be compared to concavo-convex lenses, the rims being always convex. Since finding them at Thornliebank, I have got "sockets" of similar character in the shale above the old mine at the Waukmill glen.

Fig. 5.—Cement-stone Nodule, with Shale "Sockets," from Thornliebank.

The cause of their formation has doubtless been the segregation of the cement-stone nodules, but I think they can only have been formed in a shale containing a considerable amount of bituminous matter. The Thornliebank shale is at present on fire in one part, and there is sufficient bitumen in it to reduce it when burnt to a hard red blaes. I have never seen similar "sockets" in fireclay or in light-coloured shale, even where there was an abundance of nodules.

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PROCEEDINGS FOR SESSION 1896-1897.

(39TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 15TH OCTOBER, 1896.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

The CHAIRMAN, on commencing the proceedings, spoke of the opening of a new session, the 39th of the Society's existence. He alluded to the recent death of Mr. Thomas King, professor of botany in the Technical College, one of the members who had been present at the previous meeting in June, and a member of the Council. On his motion a resolution was passed unanimously of the deep sense of loss felt by the members at Mr. King's unexpected decease, and it was agreed that an extract from the minutes to that effect should be sent to his nearest relative.

Mr. JOHN RENWICK then read a memorial notice of Mr. King, stating that he had for many years identified himself principally with botanical science in Glasgow and the West of Scotland. He had also done some good geological work, having become a member of the Society in 1874. His loss will be long felt by all who knew his unobtrusive goodness, and readiness to help all students of the natural sciences from the fulness of his scientific acquirements.

Dr. JOHN YOUNG, F.G.S., exhibited a peculiar and interesting specimen of Felsite found last autumn on the shore near Whiting Bay, Arran, by his son, Dr. Thomas Young of Manchester. The peculiarity lay in the arrangement of its numerous white, rod-like, felspar crystals into stellate groups or bundles, not exceeding ¼ inch in diameter. The rock shows clearly that this arrangement of the crystals must have taken place in this old lava during its cooling and consolidation. The specimen was found as a detached stone on the beach, and though other examples were carefully searched for, none were obtained. On a subsequent examination of the numerous trap-dykes which traverse the strata on the Kildonan shore, two were found to be composed of a felsite similar in colour and texture to that of the specimen exhibited. They also contained the same white, rod-like, bundles of crystals of felspar, but seldom arranged into stellate groups, owing, apparently, to some differences in the cooling

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of the rock. Hence, the trap of these dykes does not present so pleasing an appearance to the eye, nor has it so much interest for the mineralogist, as that of the Whiting Bay specimen.

Dr. YOUNG also spoke of the group of felspars to which the above-mentioned rod- or lathe-shaped form of crystals belongs, stating that they were now classed in the triclinic system and amongst the macroline group of this mineral.

Mr. JOHN R. STEWART exhibited a series of large Photographs of the Fossil Trees at Victoria Park, Whiteinch, which had been taken before the building was erected over them. As some injurious action was observed to be presently at work amongst these notable fossils, the Commissioners of the Burgh of Partick were very anxious to find its cause and a remedy, and had therefore sent an invitation asking the members of the Society to visit the trees, and if possible make a recommendation on the subject. A small committee was accordingly appointed to carry out the suggestion. [See the Report of the Committee at page 151.]

Captain CROWTHER, sailing-master of the "Windward," the ship which lately had the privilege of bringing home the Arctic explorer, Nansen, was introduced to the meeting, and exhibited a number of specimens of rocks and minerals, which he had picked up about lat. 79 N. by long. 48 E. Some of Cone-in-cone, though larger than Scottish examples, were in other respects very similar to them.

Mr. PETER MACNAIR read a paper entitled "Notes on the Old Red Sandstone, and the Old Red Sandstone Fishes." He briefly described the theories of Murchison and Geikie regarding the probable origin and classification of these deposits. While the former observer, on the one hand, had divided them into three groups,—upper, middle, and lower,—Sir A. Geikie, on the other, proposed to abolish the middle, or Caithness, group, placing it on the same horizon as the lower, or Strathmore, group. Mr. Macnair then proceeded to show that the evidence, whether stratigraphical, palæontological, or physical, did not warrant the extinction of Sir R. Murchison's middle group, the fauna and flora of the Caithness area being sufficiently distinct from those of Perthshire and Forfarshire to show that they could not be contemporaneous with them, but must have belonged to a later period of time. He then spoke of the origin of the various deposits, and showed that while difficulties undoubtedly existed both in the Murchison (or marine) and the Geikie (or freshwater lake) theories, he was inclined to think that the former accounted best for most of the phenomena. The ganoid fishes, which were often cited as favouring Sir A. Geikie's theory of freshwater lakes, really rather militated against it, for though the living representatives of the order are now known to inhabit only fresh water, their former world-wide distribution, and their frequent occurrence with marine shells, seemed to point to their having been at one time true inhabitants of the sea.

In illustration of his paper, besides diagrams and plates from Pander's

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great work on the Old Red Sandstone Fishes, Mr. Macnair showed a large series of Fish-remains from his own collection and from that of Mr. James Reid, Blairgowrie. Amongst the genera represented were *Coccosteus*, *Dipterus*, *Osteolepis*, *Glyptolepis*, *Pterichthys*, *Diplacanthus*, *Acanthodes*, and *Thursius*. A fine series showing the dentition of these fishes was also shown, including *Coccosteus* (a mandible), *Dipterus* (two palates with palatal teeth), *Osteolepis* (a mandible), and *Thursius* (a mandible).

SOCIETY'S ROOMS, 207 BATH STREET, 12TH NOVEMBER, 1896.

ANNUAL GENERAL BUSINESS MEETING.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. James Barclay Murdoch) read as follows:—

THE REPORT OF THE COUNCIL FOR 1895-1896.

Having reached the end of another year of the Society's work, the Council have to submit their usual annual report and statement of affairs during that period.

The MEMBERSHIP has kept well up to the average, but while that is so far satisfactory, it does not quite meet the expectations of the Council, who had hoped for a considerable increase to the roll as a result of the appeal made by circular to the members. It is to be wished that another year will see the desired addition to our numbers.

The ASSOCIATE MEMBERSHIP was renewed this year, but the number of students in Geology who took advantage of the exceedingly liberal terms offered was less than in the preceding session—rather a disappointing result to the committee on the subject.

The FINANCES are, as will be shown by the statement submitted by your Hon. Treasurer (Mr. Wight), in a sound condition, but no more than the fact need be mentioned here. [For an Abstract see page 152.]

The LIBRARY work is prospering—more books have been borrowed by more readers, as will be shown by your Hon. Librarian's report presently to be read [and printed at page 138].

The MEETINGS of the session were nine in all, extending from October to June, and were all fairly, some of them largely, attended. Many important and interesting papers were read, and a number of specimens with accompanying notes were submitted—both papers and specimens being principally local.

Amongst the PAPERS may be mentioned the following:—

"On the Old Red Sandstone and Carboniferous Rocks of Arran," by James Neilson, *V.P.* [See vol. x., part 2, page 280.]

"On a Globular Structure in a Patch of Shale enclosed in the 'Deil's Dyke' near Greenan Castle, Ayrshire." By John Smith. [See *antea*, page 128.]

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"Notes on the Proceedings at the late Meeting of the British Association at Ipswich, 1895." By James B. Murdoch. [Title only. See vol. x., part 2, page 373.]

"On a Section of Carboniferous Strata in a cutting of the Caledonian Railway at Lissens, Three Miles North-east of Kilwinning, Ayrshire." By John Smith. [See *antea*, page 122.]

"The Coast-line of Berwickshire from Eyemouth to Marshall Meadows Bay." By James S. M'Lennan. [See vol. x., part 2, page 337.]

"Stray Thoughts on the Glacial Epoch." By James White. [Title only. See vol. x., part 2, page 375.]

"The High Level Shell-beds at Clava, Inverness-shire,—a group of papers by Dugald Bell, F.G.S., and John Smith. [For Abstracts see vol. x., part 2, pages 375, 377.]

"On the Altered Basic Rocks of the Highlands as exemplified by the Sill of Hornblende Schist underlying the Loch Tay Limestone." By Peter Macnair. [See vol. x., part 2, page 302.]

"On the Genera *Lycopodites* and *Psilophyton* of the Old Red Sandstone Formation of Scotland." By James Reid and Peter Macnair. [See vol. x., part 2, page 323.]

"Account of a Recent Excursion to Calderwood Glen, Lanarkshire." By James Neilson, *V.P.* [For an Abstract see vol. x., part 2, page 379.]

"On the Occurrence of Pumice Pebbles in the Raised-beaches of Ayrshire." By John Smith. [See vol. x., part 2, page 349.]

"Additional Notes on Glen Fruin." By Dugald Bell, F.G.S. [For an Abstract see vol. x., part 2, page 380.]

"The Interglacial Beds of Ayrshire." By John Smith. [This paper has since been published in the *Transactions* under the title of "The Drifts or Glacial Deposits of Ayrshire." [See vol. xi., supplement, pages 1-132.]

"On the Occurrence of Species of the Genus *Palastræa* in the Lower Carboniferous Strata of Scotland." By James Thomson, F.G.S., *Hon. Member*. [See *antea*, page 1.]

"On the Stratified Rocks of the Shore-line from Clachland Point to the Cock of Arran. By James Thomson, F.G.S., *Hon. Member*. [See *antea*, page 12.]

Most of these papers were illustrated by maps and diagrams, and by specimens of the rocks and fossils referred to.

Of SPECIMENS a considerable number and variety were exhibited at the meetings, with notes more or less extended, and altogether the material brought forward was in excess of the time available to give it full justice.

At a special meeting the President of the Society, Sir Archibald Geikie, F.R.S., &c., gave an Address to the Members, his subject being "The Latest Volcanoes of the British Isles." [See vol. x., part 2, page 179.] It was delivered in the Large Hall, 207 Bath Street, on the evening of the 19th December, 1895, to a crowded and appreciative audience of

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members and their friends, and of members of other scientific societies to whom invitations had been sent.

The TRANSACTIONS.—The above Address and a number of the papers already mentioned will be found in the forthcoming part of the *Transactions*—vol. x., part 2—and it is expected that others will be printed in the succeeding part, several sheets of which are already in hands.

The EXCURSIONS of the year were as follows:—To Calderwood Glen, Lanarkshire, on Saturday, 11th April, conducted by Mr. James Neilson. On this visit the Section of Carboniferous strata rendered classical by the Rev. David Ure in his "History of Rutherglen and East Kilbride," 1793, was examined with interest by the large party of members present.

To Bathgate and Linlithgow, on Saturday, 25th April, conducted by Mr. Joseph Sommerville—a joint-excursion with the members of the Edinburgh Geological Society. Besides the numerous sections of Lower Carboniferous Limestone, the "Silver Mine," which had been closed for a long period, but is now re-opened, was visited, a number of the party descending the shaft. On reaching Linlithgow the members took tea together in the Star and Garter Hotel.

To Tighnabruaich, Argyllshire, on Saturday, 2nd May, conducted by Mr. M. Gemmell. The numerous shore boulders, which remain in places as thickly as they can lie, and show how the upper shores of the Clyde estuary were once similarly covered, were inspected, also the prevailing micaceous schists and intersecting trap-dykes.

To Cardross, Dumbartonshire, on Saturday, 9th May, conducted by Mr. William Armour, C.E. The Raised-beach, and glacial shell-beds, were visited, though no very good exposures were met with. The sandstones and conglomerates of the Calciferous Sandstone series were noted.

To Glen Muck and Ness Glen, Loch Doon, Ayrshire, on Thursday, 21st May, being the Queen's Birthday Holiday, conducted by Mr. John Smith. Some fine ice-polished rock-surfaces were seen, also a black sandstone, and a number of moraines. The local rocks belong to the Old Red Sandstone and Silurian formations.

To Auchinleck, Ayrshire, on Saturday, 30th May, conducted by Mr. John Smith. Several of the drift-beds mentioned by Mr. Smith in his recently-read paper on them were examined, and a number of specimens of marine shells were found at high levels.

To Arran, on Saturday, 6th June, conducted by Mr. M. Blair. Passing along the Carboniferous rocks on the shore, many granite boulders were noted, and numerous dykes of porphyry and basalt, and also several outcrops of pitchstone.

To Craigie, Ayrshire, on Saturday, 20th June, conducted by Mr. Robert Dunlop. After the Lower Limestones, with their fossiliferous shales, had been examined, the party was entertained to tea at Treesbank House, by Mr. Robert Marshall, a member of the Society.

To West Kilbride, Ayrshire, on Saturday, 4th July, conducted by Mr.

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Dugald Bell, F.G.S. The bedded traps were noted, also various trap-dykes and agglomerate necks. The red sandstones and conglomerates of Carboniferous age were traversed for some distance along the shore, and the curious patch of so-called Silurian strata was visited.

To Garelochhead, Dumbartonshire, on Saturday, 8th August, conducted by Mr. John Renwick. Various cuttings through the metamorphic rocks on the West Highland Railway were examined, and some fine glacial markings on recently-bared rock-surfaces were noted.

To Dalry and Kilwinning, Ayrshire, on Saturday, 22nd August, conducted by Mr. John Smith. An inspection was made of various exposures of the upper and lower limestones with their fossiliferous shales, also of the Boulder-clay, and numerous boulders were observed in the bed of the Garnock Water.

As will be seen, the excursions were, as in several previous years, prolonged into July and August, and judging by the good attendance of members at the later events, the change has been appreciated.

There were no Friday evening excursions this season, as Mr. James White, their former conductor, was unable to take the duty through illness, and no other member volunteered to take his place. It is hoped that they may be resumed in another year, as useful to members who cannot command the Saturdays.

Lord Kelvin's Jubilee.—The Council having arranged that the Society should take part in this auspicious ceremony, Sir Archibald Geikie, the President, and Mr. James Barclay Murdoch, the Hon. Secretary, were asked to be its representatives. An Address, signed by all the members of Council, was duly presented, and afterwards acknowledged by his lordship. [A short note of the proceedings, and a reduced fac-simile of the Address, will be found in vol. x., part 2, at pages 384-385.]

The British Association.—As in various previous years, your Hon. Secretary (Mr. Murdoch) was asked to attend the meeting of 1896 (at Ipswich) as delegate of the Society, and he gave a short account of the proceedings at the last (October) meeting of this session.

Owing to persistent efforts Scotland has now been included in the areas of work undertaken by several of the committees of the Association, from which she was hitherto excluded—amongst others, the Investigation of Underground Temperatures, of River and Coast Erosion, and of Erratic Blocks, and Geological Photography. It is therefore to be hoped that a number of the members will take an interest in, and assist in the work of, one or more of these committees.

Death of Members.—This report, unfortunately, cannot be closed without reference to the death of at least one prominent member of the Society. It has been our misfortune recently to lose Mr. Thomas King, Professor of Botany in the Technical College, and a member of our Council, one of the kindest-hearted and least self-assertive of men. It is not too much to say that his death has been felt as a loss by every one who knew him, as well as by the scientific world generally. An appreciative

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notice of the deceased gentleman was read at the October meeting by Mr. John Renwick, and will be printed, it is hoped, in an early part of the *Transactions*. JAS. BARCLAY MURDOCH, *Hon. Sec.*

The HON. TREASURER, Mr. John Wight, C.A., then read his Annual Financial Statement, which showed a favourable condition of the monetary affairs of the Society. [For an Abstract, see page 152.]

The HON. LIBRARIAN (Mr. James S. M'Lennan) submitted his Annual Report on the affairs of the Library, as follows:—

REPORT ON THE LIBRARY, 1895-1896.

Your Hon. Librarian has to report that the members have taken a larger interest in the Library during the last session, and there has been an increase of readers as well as in the number of volumes borrowed. Thus, 56 members read or consulted 280 books, while in the previous session the readers were 40, and the books issued 140, in number.

This increase is doubtless partly owing to the arrangement by which Mr. Martin of the Philosophical Society's Library is now authorised to issue the Society's books to members during any hour of the day, a change which is, manifestly, greatly for their convenience.

During the year 44 new volumes and 17 pamphlets were added, the latter all presented by their authors, as were 12 of the volumes, while the remaining 32 volumes were purchased.

On two occasions the billets for the meetings of the session contained a list of *Transactions* and other exchanges received, and also the titles of the added volumes. These exchanges comprise the *Transactions* of 26 British and 23 American and Canadian Societies.

The *Transactions* of 22 Foreign Societies have also been received, and afterwards regularly transmitted to the Mitchell Library, where the previous accumulated volumes had by arrangement been formerly sent. Members may be reminded that they are entitled at any time to consult these volumes on application to Mr. Barrett (Librarian of the Mitchell Library), and that, if wished, they can borrow them for home consultation.

Your Librarian would beg to call attention to the "Recommendation Book," which is laid on the table at every meeting, and in which members are requested to enter the title of any volume they are desirous of seeing added to the Library.

An effort will be made to have the "Supplementary Catalogue" of the Library, now in preparation, in the hands of members during the current session. JAMES S. M'LENNAN, *Hon. Librarian.*

On the motion of the Chairman, a hearty vote of thanks was awarded to the Secretaries, Treasurer, and Librarian for the very considerable work they had done on behalf of the Society during the past year.

The following gentlemen were then elected to fill the vacant places occurring in the Council at this time:—

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President—Sir Archibald Geikie, F.R.S., &c.

Vice-President—Mr. Robert Dunlop.

Members of Council—Messrs. John Dansken, F.S.I., William Maclay, William Sinclair, and James Stark.

Hon. Secretary—Mr. James Barclay Murdoch, F.R.Ph.S.E.

Assistant Hon. Secretary—Mr. Gavin M. Pratt.

Hon. Treasurer—Mr. John Wight, C.A.

Auditors—Mr. G. R. Thomson, and Mr. John R. M'Farlane.

Mr. John Cousar, 81 Hope Street, and Mr. Donald M'Cowan, Dundashill House, Port-Dundas, were elected Ordinary Members.

Miss Margaret Glass, Walmer Crescent, and Mr. Alexander Patience, 1 Clutha Street, were elected Associate Members.

The CHAIRMAN spoke of the handsome donation (£5) contributed to the Society's funds by Mr. Robert Craig of Beith, who had been a Corresponding Member for many years, and on behalf of the Council proposed Mr. Craig's nomination as an Honorary Member in slight acknowledgment of the services he had rendered to the Society.

Mr. JOSEPH SOMMERVILLE exhibited specimens of rich Gold-bearing Quartz from a district in South Africa, and made some interesting remarks upon the occurrence and distribution of gold in various parts of the world.

Mr. R. W. DRON, M.E., sent for exhibition several specimens of Gold-bearing Rocks from Montana, U.S.A., which he had recently visited. Some of these contained considerable percentages of the precious metal.

Mr. GAVIN M. PRATT, Assistant Hon. Secretary, exhibited, for Captain Crowther, sailing-master of the "Windward," specimens of Rocks and Fossils from the Arctic regions, collected on her recent voyage. They comprised Silicified Pine-wood, Crystallised Carbonate of Lime, Rock showing Cone-in-cone structure, from Cape Flora, Septariated Clay-nodule, Felstone Porphyry Boulder, Silicious Pebbles, Lead Ore (Galena) with Silver, from Cape Farewell, Greenland. [See page 133.]

Some remarks on the specimens were made by Mr. Pratt, Dr. John Young, F.G.S., and other members.

Mr. JAMES S. M'LENNAN, Hon. Librarian, read a paper on "The Shode Valley in Kent," which locality he had visited in the course of last summer. He described the district, which is known as the "Garden of England," as having many attractions for the lover of nature, antiquarian, anthropologist and geologist. He detailed more particularly the geological features of the neighbourhood of Ightham, about 25 miles south-east of London, where the steep slope of the Chalk escarpment is seen stretching west by north for miles. The surface of this chalk plateau, which is from 400 to 800 feet above sea-level, has in many places a covering of Red Clay Drift with intermingled flints. Directly south of the Chalk escarpment there runs at a distance of 4 or 5 miles a counterscarp of rocks belonging to the Lower Greensand. This is pierced by a valley through which runs

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the small stream of the Shode, which falls into the Medway near Hadlow. Besides the Cretaceous rocks and Lower Greensand, the author described the Upper Greensand, the Gault, the Kentish Rag, and the various superficial deposits. He also described the remarkable rock-fissure of the locality, and its contents—animal remains—which had been discovered and noted by Mr. W. J. Lewis Abbott, F.G.S., under whose guidance the writer had visited it.

The paper was illustrated by a large number of specimens of natural and worked flints, &c.

A paper by Mr. J. B. MURDOCH, *Hon. Sec.*, "On the Recent Meeting of the British Association at Liverpool," was held over from want of time.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH DECEMBER, 1896.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

Mr. Robert Craig, King College, Beith, was elected an Honorary Member.

Mr. James Young, jun., Carleon, Bearsden, was elected a Life Member.

The CHAIRMAN (Mr. Neilson) paid a feeling tribute to the memory of the late Mr. David Robertson, LL.D., F.L.S., F.G.S., whose death had quite recently occurred, and spoke of his long connection with the Society, of which he had been a member since 1866. Mr. Neilson also referred to the many contributions which Dr. Robertson had made in past years to its *Transactions*.

Dr. John Young, F.G.S., Mr. James Steel, and the Hon. Secretary (Mr. Murdoch), also remarked upon the scientific work of the deceased gentlemen, and after a motion of deep regret at his death had been unanimously passed, it was agreed that an extract from the minutes should be forwarded to Mrs. Robertson and her family.

Mr. ROBERT DUNLOP, *Vice-President*, exhibited a large series of Photographs recently taken by himself, principally at excursions of the Society, which included many fine rock-sections, and other geological phenomena in the West of Scotland. Remarks upon these were also made by Dr. Young and other members.

Mr. DUNLOP also exhibited a large piece of Shale from the Phillipstoun oil-shales of the Calciferous Sandstone, near Linlithgow, which appeared to be the rough outer bark of a large tree, of which the genus and species were as yet undetermined.

Mr. JOHN SMITH read a paper on "The Occurrence of Certain Curious Concretions or Nodules in Boulder-clay." He stated that after he knew of the existence of these bodies, he had lost no opportunity of searching for them in the banks and scaurs of the Ayrshire streams, with the result that he had only detected 19 specimens (which he exhibited), a proof of their rarity. They were probably formed through the gathering together

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of carbonate of lime, in some places probably irony matter, round a central nucleus, or perhaps merely through the attraction of one molecule of lime or iron for another.

A subsequent discussion was taken part in by Dr. John Young, F.G.S., Messrs. Robert Dunlop, J. S. M'Lennan, James Steel, and the Chairman (Mr. Neilson). The latter stated that he had now come to the conclusion that every nodule in shale had been formed round an organic nucleus, whether animal or vegetable, through the action of gases evolved during the process of decomposition, which led to new chemical combinations between these gases and certain constituents of the rock. It was beyond dispute that many nodules had organic nuclei, and though not apparently present in others it was extremely probable, to say the least, that in such cases the original central organisms had not possessed a hard skeleton or crust, or a horny shell, and had therefore entirely disappeared, leaving no traces of their existence except the hardening of the material for a certain distance round them.

Mr. JOHN SMITH read, secondly, a paper on "The Occurrence of Amygdules and (Minute) Perfect Crystals of Quartz in 'Sooty Coal' found at Sevenacres, Kilwinning, Ayrshire." This coal, probably the remains of the Main Coal of the district, crops out in the upper edge of the bank above Lugton Water, near Sevenacres. In some places it has been converted into a hard columnar coke, where it has been in close contact with sills, or ramifying veins, of trap, probably the same agency which caused its general soft, sooty-looking appearance. The amygdules found in the coal are small whitish nodules, probably of lime, iron, &c., sometimes crystalline, with smooth surfaces. They resemble certain genera of foraminifera both in size and shape, but are purely mineral. The minute quartz crystals present many forms, often having double pyramidal terminations, and they show great beauty under a low power of the microscope. The author's theory of their formation was that they were formed from silica in the ash of the burnt coal, and this was the more probable, as "blebs" of pure glass, doubtless the result of the combination of silica with an alkali, were found amongst them.

The paper was illustrated by a number of specimens, the quartz crystals being shown under the Society's microscope. Remarks upon the various points raised were made by Dr. John Young, F.G.S., Mr. Robert Dunlop, and Mr. George R. Thomson.

The HON. SECRETARY (Mr. Murdoch) on behalf of Mr. Robert Craig, who was unable to be present from illness, read a paper entitled "Notes upon Boulders in Cuttings on the Joint Railway between Kilmarnock and Stewarton, and elsewhere in the district."

This communication referred to the boulders met with by the author, principally those embedded in the Boulder-clay on the floor of the railway cuttings. Owing to unforeseen circumstances—a 30 per cent. rise of wages, amongst others—the completion of the railway was delayed for nearly two years, and the exposed boulders became beautifully washed by rain, show-

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ing the very faintest striations upon them. Of all those fixed in the clay their position, and the direction of their striations, were taken by compass, the result being that, while the majority bore out the general theory that boulders are striated conformably to their long axes, a number were found to be striated at right angles to this, and at all angles from it. The same diversity was observed as to the lie of their positions. A few lay conformably with the striations of the rocks near by, while others were in all sorts of positions across the striæ.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH JANUARY, 1897.

Mr. ROBERT DUNLOP, *Vice-President*, in the Chair.

Mr. John Orr, 12 Newhall Terrace, was elected a Life Member.

Mr. JAMES THOMSON, F.G.S., exhibited a number of specimens of the coral genera, *Phillipsastræa*, *Lithostrotion*, and *Diphyphyllum*, illustrating his remarks by diagrams on a large scale.

Mr. JAMES S. M'LENNAN, *Hon. Librarian*, read a paper on "Eolithic Flint Finds near Ightham, Kent." The little picturesque village of Ightham is situated on the eastern slope of the sandy ridge on which the town of Seven Oaks is built, and faces a noble sweep of the North Downs, stretching to the Medway at Rochester on the east, and to Guildford in Surrey on the west. The slope of these Downs forms the escarpment of the Chalk plateau which in places rises to 700 or 800 feet above sea-level. Ightham, which lies in a hollow, is a typical Kentish village, its houses, built of "rag" with red tile roofs, being enveloped in greenery, which in spring and summer gives them a very charming appearance. Contiguous there are numerous fruit gardens and orchards bounded by pine woods. On one of the low Greensand hills near by—Oldbury Hill—there are the remains of an ancient British camp, with evidences of rock-shelters. South of Ightham there is a diversified country, the upper rock being Lower Greensand, overlaid in places by river gravels. These deposits have been found to contain flint implements in numbers, chiefly through the long and persevering researches of Mr. Benjamin Harrison, "grocer and geologist" of Ightham, who attracted to the study of natural history as a boy by the perusal of White's "Selborne," afterwards took up the kindred branches of geology and archæology. The discovery of flint implements in the valley of the Somme in France induced Mr. Harrison to examine the Shode valley near his native village, and afterwards to explore the Holmsdale valley, with the result that in the gravels of both he found many palæolithic flints. In 1885 Mr. Harrison turned his attention to the remains found on the surface of the Chalk plateau, about 700 feet above sea-level. Recent investigations have shown pretty clearly that these plateau flints are of a ruder and older type than those of the river gravels of the valleys, and they are therefore now classed as eolithic, as distinguished from the later neolithic and palæolithic types. The late Sir Joseph Prestwich took a deep interest in

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Mr. Harrison, and did much in his writings to bring the work of the grocer-geologist into the prominence it deserved, as well as to settle the much-debated questions as to the origin of these prehistoric remains. It has been Mr. Harrison's practice to keep a correct list, and to make a sketch, of every specimen he has found, as well as to mark the spot where it was got, on the 6-inch Ordnance map. Most of his flint-hunting has been done after early dawn, so that he might reach home in time to open his shop at the regular hour in the morning. Mr. M'Lennan then described a visit he had made to Ightham last year, his meeting with Mr. Harrison, and inspection of his fine collection. He then began to hunt for himself, and was successful in obtaining a number of undoubted flint implements, which he described in the remaining part of his paper.

The paper was illustrated by a number of the specimens referred to.

Mr. JAMES NEILSON, *V.P.*, in illustration of the same subject, showed a large series of Flint Implements from Irish and Scottish localities.

The CHAIRMAN (Mr. R. Dunlop) exhibited a series of Fish Remains from the Lanarkshire oil-shales, including bones and teeth of *Ctenacanthus* and *Palæoniscus*, and Mr. James Thomson, F.G.S., made some remarks on the various specimens.

The HON. SECRETARY (Mr. Murdoch) read on behalf of Mr. John Smith, who was unable to be present, a short paper entitled "A Theory on the Production of Schistose Structure in Rocks." When splitting an old tree with mild steel wedges the author found that the heads of the wedges, by constant hammering, began to be bruised, and flattened out, and to take a schistose (or split up) structure, the laminæ being wrinkled and puckered, much like some of the well-known Highland schists. It then occurred to him that some "hammering" forces in nature, such as those of earthquake shocks, may have produced much of the appearances hitherto attributed to the effects of lateral pressure alone. The paper was illustrated by specimens of the steel wedges, and of wrinkled schists.

A paper by the Hon. Secretary, "On Some Recent Landslips," was held over from want of time.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH FEBRUARY, 1897.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

Mr. JAMES NEILSON, *V.P.*, referred to the recent death of a well-known member—Mr. Adam Knox. His connection with the Society had lasted for over thirty years, and at the time of his death he was a member of Council. Mr. Neilson moved that a vote of condolence should be passed, and that an extract from the minutes should be sent to Mrs. Knox, which was unanimously agreed to.

Mr. A. M. Burden and Mr. Alexander Mackay were elected Associate Members.

Mr. JAMES NEILSON, *V.P.*, exhibited a rock-specimen, bearing a remarkable resemblance to the coral *Lithostrotion Portlocki*, which he had obtained

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from the Calciferous Sandstone series in West Bay, near Millport, in the island of Cumbrae. He stated that the specimen was an entire puzzle from its striking simulation of the above-named well-known coral. It possessed no structure, however, being composed of a hard sandstone, with conglomerate pebbles of quartz, up to half an inch in diameter, scattered through it. Dr. John Young, F.G.S., and other members, made observations upon this curious specimen.

Mr. JOSEPH SOMMERVILLE exhibited, under the microscope, Minute Quartz Crystals which he had extracted from the columnar coal found at Blackhill, their occurrence in metamorphic coal showing the presence of silica, probably in solution, at the time of their formation.

Mr. SOMMERVILLE read a short paper on "Phlogopite (Star Mica), with special reference to the Cause of the Asterism." He stated that this mineral is a magnesian mica proper, containing very little iron, and, according to Dana, not sharply separated from biotite, but so far constant and peculiar in character and occurrence as to be naturally placed by itself. On making a microscopical examination of a number of specimens, which he had obtained in Canada some years ago, he came to the conclusion that the asterism of this form of mica was due to the presence of minute crystals or inclusions of some kind, arranged in definite lines. In a recent lecture by Lord Kelvin, "On the Molecular Dynamics of a Crystal," his lordship stated that the star rays shown by phlogopite were produced by extremely minute cracks in the mica. Led by this to re-examine his Canadian specimens Mr. Sommerville said that he still remained confident he was correct in his first opinion. A point which he had never seen noticed by any of the authorities was, that, as seen under the lens, the rays of light in a specimen of star mica are reflected at right angles to the lines in which the inclusions are seen to lie. Of this phenomenon he was not prepared to give any explanation at present.

The paper was illustrated by a large series of specimens of phlogopite, and other varieties of mica, also by microscopic sections, diagrams, and sketches.

Mr. PETER MACNAIR read a joint paper by Messrs. Reid, Graham, and himself entitled "*Parka decipiens*, its Origin, Affinities, and Distribution." [See *antea*, page 109.] It was illustrated by a large series of specimens, by microscopic slides, by diagrams, drawings, and maps.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH MARCH, 1897.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) stated that Mr. Peter Macnair had been elected to fill the vacancy in the Council caused by the regretted death of Mr. Adam Knox.

Mr. WILLIAM ARMOUR, C.E., proposed the following motion, of which notice had duly been given at the previous meeting—"That a sum not exceeding £10 of the Society's funds shall be devoted to the use of the

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Library during the current session." This was seconded by Mr. James Steel and unanimously agreed to.

Mr. JOHN SMITH exhibited a Stone Hammer found in the workings of an old gold mine, 14 miles east of Umtali, South Africa, which had been sent home by the late Mr. Edward Carrick, mining commissioner there. It was got in an old "stope," at a depth of 45 feet from the surface, and beside it lay a splinter of rock about 9 inches long, which had evidently been used as a chisel or "gad" for the extraction of the ore. He stated that Mr. Edward Carrick was one of the younger members of the Society, and that he went to Africa some years ago. He had promised to contribute to the *Transactions* a paper on the geology of the district of Umtali, but unfortunately was killed by the natives at his post in 1896. For comparison with the South African implement Mr. Smith exhibited two Stone Hammers found by himself in Ayrshire, which bore a great general resemblance to it. All had similar indentations on two sides, giving a good grip for the finger and thumb.

Mr. JOHN HORNE, F.R.S.E., F.G.S., of H.M. Geological Survey, and President of the Edinburgh Geological Society, read a paper on "Graptolites as Indices of Stratigraphical Horizons." At the outset, after briefly reviewing the recent researches of Lapworth, Ruedemann, Nicholson, and Marr, on the morphological development of graptolites, the author proceeded to indicate the distribution of the group in time. He referred to the physical and palæontological evidence in the Silurian basin of Bohemia which led to the well-known doctrine of colonies advocated by Barrande, and showed how this theory failed to explain the anomalies—palæontological and physical—of the Silurian uplands of the South of Scotland. The researches of Prof. Lapworth, based on the vertical distribution of the graptolites, had placed the order of succession of these strata on an impregnable basis. The subsequent discovery by the officers of the Geological Survey of a zone of cherts, charged with Radiolaria, and analogous to the Radiolarian ooze of existing seas, had likewise proved of great service in unravelling the complicated structure of the Southern Uplands. These cherts, which underlie graptolite shales of Upper Llandeilo age, rest upon a series of Arenig volcanic rocks. It has now been conclusively proved by Professor Lapworth's prolonged investigations that certain species of graptolites are restricted to certain definite horizons, and this has enabled geologists to correlate, more successfully than hitherto, the Silurian rocks of Great Britain with those of other regions. The lecturer paid a high compliment to the work of a member of the Society, the late Mr. James Dairon, amongst the Scottish graptolites, and expressed the hope that other members might continue the examination of the graptolite zones of the Southern Scottish Uplands.

The paper was illustrated by a large series of maps and diagrams, and by drawings and sections thrown on a screen by the oxyhydrogen lantern.

At its close remarks were made by Dr. John Young, F.G.S., Mr. James Thomson, F.G.S., and the Chairman (Mr. Neilson), and a hearty vote of

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thanks was awarded to Mr. Horne for his kindness in coming from Edinburgh to address the Society.

Rev. DAVID LANDSBOROUGH, Kilmarnock, read a short paper upon the occurrence of Dendritic Markings, the result of the crystallisation of manganese, in the Red Sandstone of Ballochmyle, Ayrshire. A photograph of one specially fine slab, at present deposited in the Kilmarnock Museum, measuring 4 feet by 2 feet, and drawings of several others, were exhibited.

Mr. Landsborough also exhibited a specimen of Red Sandstone from Ballochmyle, showing a number of concentric ring markings. In these the original red had been discharged, and the colour now varied from white to black.

In further illustration of Dendritic Markings Mr. John Kirsop sent for exhibition a fine collection of cut Agates, including the variety known as "Moss Agate," which owes its "moss" or fernlike structure entirely to this form of crystallisation.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH APRIL, 1897.

Mr. ROBERT DUNLOP, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) referred to the recent death of Mr. William Kirkland, the first secretary of the Society, from the effects of an accident which he met with in Argyll Street. He was one of the four young men, members of a Literary Society connected with Free St. Peter's Church, who met on 10th May, 1858, and drew up an advertisement calling a meeting of those willing to join a society for the study of geology. A subsequent meeting held on 17th May resulted in the formation of this—the Geological Society of Glasgow. Mr. Kirkland did much arduous work in the launching and carrying on of the new venture. Though soon retiring from the secretaryship he, up to the last, took a warm interest in its welfare.

Mr. JAMES THOMSON, F.G.S., made some remarks upon his remembrances of the deceased gentleman, and proposed a motion of regret at his untimely death. He also proposed that an extract from the minutes should be sent to Mr. Kirkland's nearest relatives, and this being seconded by Dr. John Young, F.G.S., was unanimously agreed to.

Mr. James Russell, C.E., 138 Bath Street, and Mr. Archibald Shanks, Analytical Chemist, James Street, Dalry, Ayrshire, were elected Ordinary Members.

Mr. JOHN SMITH read an abstract of an exhaustive paper on "The Drift or Glacial Deposits of Ayrshire," giving the results of his extensive investigation into the Boulder-clays of the county during the past two years. In the course of this he had carefully examined about 280 sections of stratified beds—Boulder-clay, sand, gravel, and peat—the Boulder-clay being met with at all levels up to 1750 feet above the sea. Many of the beds contained numerous marine shells, some in a perfect condition, from

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below sea-level to nearly 1100 feet above it. The area in which these sections lie extends for about 46 miles from north to south by about 25 miles inland from the coast-line. After giving a general description of them Mr. Smith proceeded to inquire how such extensive masses of material had been deposited, and stated he had come to the conclusion that they were true marine deposits, laid down, generally speaking, in the positions they now occupied, though a few bore evidences of having been dragged by land-ice. He could not admit that they were, according to the theory advanced by some geologists of the present day, the products of "waves of translation," or of moving masses of land-ice.

The paper was illustrated by a map of Ayrshire, by coloured diagrams, and by specimens of the marine shells found in the Drift Beds. At its close an interesting discussion was taken part in by Dr. John Young, F.G.S., Messrs. James Thomson, F.G.S., William Armour, C.E., James Neilson, *V.P.*, J. S. M'Lennan, Joseph Sommerville, and the Hon. Secretary (Mr. Murdoch), the general opinion expressed being that Mr. Smith's contribution was one of the most important ever submitted to the Society. In his remarks Mr. Armour stated he had recently visited Mr. Dugald Bell, who unfortunately had been laid aside by severe and, it was to be feared, fatal illness.* He still took a deep interest in the question of the Drift deposits, and was able to discuss Mr. Smith's general conclusions as to their origin, remaining, however, of the opinion that the presence of marine remains in the Ayrshire Boulder-clays might be accounted for by the great congestion of ice in the Clyde Valley, which had pushed up some of the deposits containing sea-shells over the elevated ground on either side of the Firth by the enormous pressure which it exerted. He had not, however, been able to examine the details of Mr. Smith's work.

SOCIETY'S ROOMS, 207 BATH STREET, 6TH MAY, 1897.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

Mr. Charles M'Neil, Forgemaster, South Cliff, Wemyss Bay, was elected a Life Member.

Messrs. Archibald Donaldson, 143 Abercromby Street, William Jeffray, 110 Barrack Street, Peter Johnston, Underwood Villa, Langside, and A. G. Neilson, 9 Hillside Gardens, Partickhill, were elected Ordinary Members.

Mr. JAMES NEILSON, *V.P.*, gave an account of the stratified rocks which had been met with during the excavations for the new deep-level sewer at present being constructed in Alexandra Parade, Dennistoun, the presence of *Anthracosia* and *Lingula* indicating their true horizon, which he believed to be near the bottom of the Upper Carboniferous series. The marine shells occupy a distinct bed, from which the *Anthracosia* (*Carbonicola*) group is absent. This appeared to be one of the very rare instances where

* To the great loss of his friends and the Society Mr. Bell died on 15th January, 1898, after a prolonged illness.

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a marine bed has been found in the Upper Coal measures. In illustration of his remarks Mr. Neilson exhibited a collection of the various molluscan and plant remains which had been found in the shale beds.

Mr. JOHN RENWICK gave an account of the Society's recent excursion to Craigmaddie Moor. In describing the outstanding feature of the district —the "Auld Wives' Lifts"—of which he exhibited several fine photographs taken by members of the Society, he noticed the different theories put forward from time to time to account for the presence of these enormous blocks of sandstone upon the lonely moorland—that they had originally been brought to their present position to form a cromlech, that they are simply ice-borne blocks, or that they are simply weathered-out portions of the existing sandstone strata. A discussion followed and was taken part in by several members.

Mr. W. A. Donnelly, of Bowling, the well-known artist, exhibited a fine sepia drawing of these great blocks, which he had sketched on the occasion of the excursion.

Rev. FREDERICK SMITH read a paper entitled "Some Functions and Phenomena of Rivers." At its commencement he described the dead waters of the River Earn, near Forteviot, and explained the manner of their formation by the action of the stream. He then laid down the following axioms as applicable to all river-action :—1st. A river accumulates debris on the inner bank of its curves, and denudes away material from the outer one. 2nd. A river builds up its "haugh-lands" to the height of its highest flood-mark. He next dealt with the types of perpendicular deposition, as explained by these axioms, and entered into a detailed description of the dispersive and accumulative periods of a river's work, as seen in the valleys of the Tay, the Earn, and other large Scottish streams.

The paper was illustrated by a large series of diagrammatic sections, and at its close remarks on the subject were made by several members.

Rev. Mr. SMITH then exhibited a large series of specimens of Scottish Palæolithic Weapons and Implements, collected by himself, largely from river-deposits, and compared them with the "official forms" found in France in the Valley of the Somme, and in the South of England in the Thames valley and elsewhere. He maintained that, so far as form was concerned, these Scottish specimens were as good as many of the English ones, and that, if the extreme differences in the material of which they were formed were taken into account, there could be little doubt the former had been fabricated by the hand of man equally with the latter. Mr. Smith also spoke as to the distribution of these forms in the river-deposits, and showed that their mode of occurrence in certain horizons was highly indicative of their artificial distribution. In a following discussion remarks were made by Mr. James Neilson, *V.P.*, Mr. Donnelly, and the chairman, and a hearty vote of thanks was awarded to Mr. Smith for his interesting communications.

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SOCIETY'S ROOMS, 207 BATH STREET, 27TH MAY, 1897.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

Mr. Robert S. Houston, Evandale, Hawkhead Road, Paisley, was elected an Ordinary Member.

Mr. JOHN RENWICK exhibited a fine series of Teeth of Sharks of the genus *Lamna*, found in a phosphate bed near Tebessa, Algeria, about 100 miles inland, and 4000 feet above sea-level. They appeared to have come from either a Miocene or a Pliocene formation. Dr. John Murray of the "Challenger," to whom they had been submitted, stated that on one occasion he had brought up when dredging 600 similar teeth from a depth of two-thirds of a mile.

Mr. PETER MACNAIR exhibited a series of specimens of Banded Hornblende Schists from Balhoulan Quarry, near Pitlochry, Perthshire. In the course of his remarks he pointed out that the hornblende schists of the Highlands are now generally admitted to be of igneous origin. He referred to the difficulty which arose as to how such banded structures could have been produced, and spoke of the possibility of their having been caused by original fluxional movements while the rock was still in a molten condition. From this he proceeded to describe the views put forward by Mr. Harris Teall, who thought that the finely banded structures met with in certain gneisses could have been produced by dynamic metamorphism acting upon a complex of plutonic rocks. Mr. Macnair then applied this theory to account for the banded structure shown in the present specimens, his belief being that the original basic rock had entangled fragments of the surrounding grits, into which it had been intruded, so as to form a rock-complex, and that when this complex had been subsequently subjected to dynamic metamorphism the heterogeneous mass had become drawn out into the banded structure we now find. In conclusion he referred those interested in the subject to a paper by Mr. Henry Coates, F.R.S.E., and himself, published in the *Transactions of the Perthshire Society of Natural Science*, vol. ii., 1897, page 154, which gave a detailed account of the interesting section at Balhoulan.

Mr. Macnair's remarks were illustrated by a number of photographs, and by a microscopic section of the banded rock.

Mr. JAMES NEILSON, *V.P.* (the chairman), exhibited a further series of Carboniferous Fossils collected from the material removed from the new Dennistoun sewer. [See page 147.] These included a number of *Goniatites*, a chambered shell allied to the modern Nautilus, many species of which are known in England, and a greatly less number in our local strata at Campsie, Craigenglen, and Robroyston.

The HON. SECRETARY (Mr. Murdoch), exhibited, on behalf of Mr. William Ker, a fine rock-specimen showing the Junction of the Granite and the

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Slate, taken from the Cioch Burn, near Corrie, Arran, and made some remarks upon it.

A number of Reports on Recent Excursions of the Society—to Bowling, Dumbartonshire; Killin and Glen Ogle, Perthshire; Gourock and Cloch, Renfrewshire; and Darvel, Ayrshire—were read by their respective conductors, Messrs. James Neilson, Peter Macnair, James Steel, and John Smith, many points of interest having been noted.

On the Bowling excursion the cup-and-ring markings on the sandstone rock-faces in Auchentorlie estate had been visited, and it was observed with great regret that, though only exposed a few years ago, the markings were showing strong signs of weather-deterioration, which was progressing at a rate that in a very few years would compass the entire obliteration of these interesting remains.

Several of the members spoke on the subject, and it was generally agreed that some steps should if possible be taken to avert such a misfortune.

Mr. JOHN SMITH read a paper on "The Exploration of a Rock-shelter and Shell-mound on the Carrick shore of Ayrshire." This natural sea-cave in the red sandstone has a level of 10 to 12 feet above storm-tides. It has a peculiar set of "seats" or benches on its floor, which have been hewn from the solid rock, having all their front faces segments of circles. The makers of these curious "seats" do not appear to be represented by any other traces of their occupation of the cave, but the subsequent inhabitants—the race which accumulated the shell-mounds found at intervals all round our coasts—had made use of it for a long period of time, as may be seen from the debris which entirely covers the floor and "seats," in places to a considerable depth. Excavations yielded numerous bones of animals, including those of the ox, pig, sheep, rabbit, and various fishes, and shells of many edible molluscs. There were also fragments of hand-made and wheel-turned pottery. Except several broad-headed iron nails, and a fragment of sheet copper there was no metal, and there were no implements or articles of human use except a piece of pottery, the edges of which showed signs of its use as a "scraper," and a fragment of dogfish bone, apparently used as an awl. After discovering the stone "seats" Mr. Smith communicated with the late Mr. Cochrane Patrick, who said that in all his experience he had never met with a similar example. This feature of the Carrick cave may therefore be pronounced unique in Scottish archæology.

The paper was illustrated by some fine photographs taken by Mr. Robert Dunlop, and by the author's own drawings.

The CHAIRMAN (Mr. Neilson) then declared the session to be closed, and expressed a hope that the members would have a pleasant rambling-time in the succeeding months, coming back with some interesting notes to lay before future meetings.

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FOSSIL TREES AT WHITEINCH.

Report by the Committee appointed to advise as to the Preservation of the Fossil Trees within the Fossil House, Victoria Park, Whiteinch, belonging to the Commissioners of the Burgh of Partick.

Committee—John Young, LL.D., F.G.S., William Armour, C.E., Joseph Sommerville, and John Dansken, F.S.I., F.R.A.S., *Vice-President*, Convener.

As instructed at the October meeting of the Council of the Geological Society of Glasgow, the members of the Committee visited the Fossil House at Victoria Park, met Commissioners Bowie and Brown, and the Superintendent of the Park, heard them as to the preservation of the Fossil Trees, and, specially, as to the propriety of introducing artificial heat within the building. The Committee examined the Fossils and their surroundings and having fully considered the matter beg to report unanimously—(1) That no artificial heat should be introduced into the Fossil House. (2) That the preservation of the Fossil Trees would be best secured by adopting means to prevent the inflow of rain and underground water into the Fossil House. It is suggested that a trench should be dug on the north and south sides of the house, keeping clear of the foundations, and making it deep enough to prevent the inflow of water to the house, and with sufficient declivity to allow the water to run off immediately to the west. The Committee is of opinion that it would not be needful to cut the trench deeper than the bottom of the lowest bed that enters the house. Should the Burgh Commissioners entertain the above suggestions the Committee would be glad to advise with them as to the most economical method of carrying them out.

(Signed) JOHN DANSKEN,

Convener of Committee,

11*th November*, 1896.

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1896.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£170	0	0			
Cash in Treasurer's hands,	2	11	4			
				£172	11	4
Life Membership Subscription,				5	5	0
Subscriptions for current year, and Arrears (£1 10s.),				77	10	0
Associate Membership Subscriptions,				1	10	0
Interest on Funds,				7	19	7
Publications sold,				2	3	10
Donation,				5	0	0
Legacy from late Sir Michael Connal: third instalment,				2	5	0
				£274	4	9

Note.—The Legacy was £10, of which £5 12s. 6d. has been paid.

DISBURSEMENTS.

Printing *Transactions* and Papers,	£60	5	0			
Plates for ditto,	5	16	5			
Reporting Sir Arch. Geikie's Address,	1	10	0			
				£67	11	5
Rent, Insurance, and Attendance,	£14	10	0			
Collector's Commission,	3	8	0			
Postages and Petty Expenses,	2	8	2			
Printing Circulars, &c.,	9	3	3			
Disbursements by Secretaries and Librarian,	10	4	2			
				39	13	7
New Books,				8	15	11
Subscription to Palæontographical Soc. for Two Years,				2	2	0
,, Marine Station, Millport,				2	2	0
Prizes to Associate Members,				2	19	9
Cash in Bank,	£145	0	0			
Cash in Treasurer's hands,	6	0	1			
				151	0	1
				£274	4	9

STOCK ACCOUNT.

To Balance to Credit,				£821	0	1
				£821	0	1

By Cash in Bank and on hand,				£151	0	1
,, Funds Invested,				170	0	0
,, Property—Books,	£440	0	0			
,, Furniture, Bookcases, and Microscope,	60	0	0			
,, Fossils (not valued),	0	0	0			
				500	0	0
				£821	0	1

GLASGOW, 22nd October, 1896.—Examined and compared with vouchers and found correct, the balance in Treasurer's hands being £6 0s. 1d.

JOHN R. M'FARLANE, }
JOHN BOYD, } *Auditors.*

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY

OF GLASGOW.

VOL. XI.—PART II.

1897-99.

GLASGOW: PUBLISHED BY THE SOCIETY,
AT ITS ROOMS, 207 BATH STREET,
1900.

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The Editor begs to state that the Authors are alone responsible for the facts and opinions contained in their respective papers.

JAS. BARCLAY MURDOCH, F.R.PH.S.E.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. XII.—On the Structure of Agates. By the late M. Forster-Heddle, M.D., Emeritus-Professor of Chemistry in the University of St. Andrews, Hon. Member. With Thirty Illustrations from Drawings by the Author.

Chalcedonic and zeolitic druses represent the former vapour vesicles of igneous rocks, which vesicles have, after partial alteration of the latter, been more or less completely filled by the deposition of decomposition-products of the several minerals which compose the rocks. These decomposition-products have been carried in solution—probably in water—into the vesicles by endosmose—as into shut cavities. Within the vesicles they have been deposited in successive layers, through which layers endosmose continued to act. After the deposition or coagulation of the material forming the layers, the solvent liquid was forced out of the cavity through one or through many openings by the entrance of a new quantity of strong solution, according to the ordinary law of endosmose. These openings may be called *tubes of escape.*

When the druse has been more or less completely filled by the various modifications of silica—hydrated or anhydrous—it is termed an agate, but no absolute line can be drawn to separate such from a *zeolitic* cavity, as one cavity may contain both siliceous layers and zeolites, and that in varying order of superposition. Neither can it be definitely stated which ingredients of

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the rock by its decomposition determines the formation of either; but this distinction has to be pointed out in the formation or filling-up of such druses, namely, that there is *a perfectly definite order* in the successive deposition of the various zeolitic minerals which fill drusy cavities, while there is no definite order whatsoever in the deposition of the various forms of silica, the layers of which form an agate.

It is the formation of this last which is here considered.

AGATES: NORMAL STRUCTURE.

Form.

The form of the vapour-vesicle is determined by the amount of fluidity or of viscosity of the flow through which it is ascending; and also by the state of the flow—whether of motion or of rest. If it had little or no motion and great fluidity, the vesicle, especially if it be small, is *round.* When the viscosity of the lava was so great that the vesicles rose with difficulty while the flow still continued, the vesicles have been drawn out into more or less of a *rod-shaped* form, and often lie horizontally—the more rounded extremity pointing in the direction of the flow. If there has been little motion and considerable fluidity the vesicle is *pear-* or *balloon-shaped.* If some motion and considerable fluidity it is *axe-shaped* (fig. 1). If rapid motion and considerable fluidity it is *lanceolate.* When very large there is frequently an elevation in the centre of the floor, as in a *wine bottle.* Agates with a flat side are almost invariably *onyx-agates* (fig. 2). The flattening may have resulted from the matrix concreting and solidifying at a uniform distance from the underlying cooling surface: (as this surface has been probably somewhat sloping, the onyx banding, which is invariably horizontal, does not always absolutely accord with the flat surface). When, subsequent to solidification, a rent has been formed in the rock, the rent may, when not opening to the surface, become coated on both sides with chalcedony, and so form a *vein-agate.*

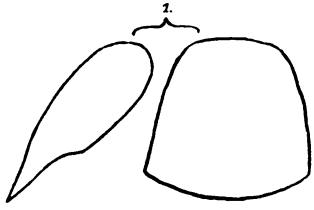

Fig. 1.—Axe-shaped Agate in two positions.

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The Layers.

The substances which form the layers or bands of agate are—the skin, chalcedony, carnelian, cacholong, girasol opal, wax opal, —all of these are colloids—and hydrated silica; quartz, amethyst, cairngorm,—all of which are crystalline—and anhydrous silica. Jasper rarely occurs.

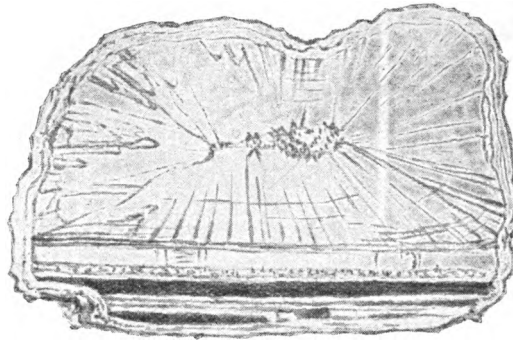

Fig. 2.—Onyx-Agate: Onyx parallel to flat side, Druse filled with Quartz.

These several substances may be deposited in any order from without inwards (figs. 3 and 4)—the hydrated varieties being usually the earlier deposited. Clear chalcedony usually forms the outer

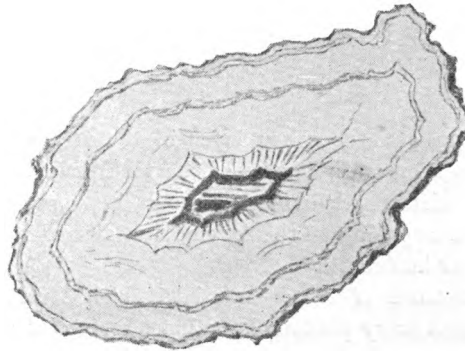

Fig. 3.—Varying Order of Deposition.

layer—after the skin; this is succeeded by milky chalcedony, or by cacholong. Amethyst, quartz, or carnelian, usually form the centre. When quartz or amethyst is in quantity, and is the last

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deposited layer, an unfilled central cavity often remains. When carnelian fills the centre it is frequently rent. At some localities girasol or milk-opal forms the outer zone.

The regular concentric deposition of the layers of an agate is due to a considerable and uniform amount of adhesion between the surface of each layer and that of the layer previously deposited. When that adhesion is weak the layer may be somewhat thickened towards the lower part of the cavity,—gravitation in this case operating upon the only partially solidified chalcedony.

Fig. 4.—Varying Order of Deposition.

The Skin.

The first or outer-deposited layer in the vesicle results from the decomposition of the augite of the rock matrix. This layer consists of either celadonite, chlorophæite, or delessite. If labradorite or nepheline in the rock be also altered it may consist of natrolite or heulandite.

The first three of these materials which form the "skin" invariably coat every portion of the inner surface of the cavity.

If it be present in *unusual* amount it appears in threads pendulous from the upper part towards the lower part of the cavity (fig. 5). Such threads, upon the after-injection of siliceous solutions, determine the formation, and form the centre of so-called *stalactites.*

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When it is in *large* amount it is deposited as an interlacing net-work of fibres. These, upon being sheathed by the ingress of siliceous solutions, determine the formation of *moss-agates* (fig. 6).

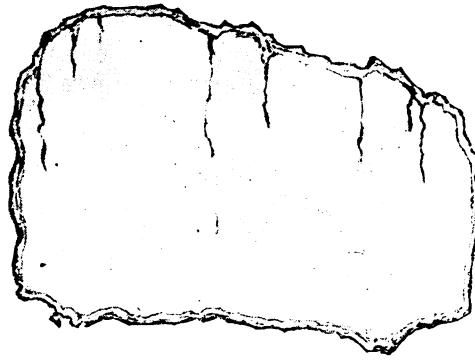

Fig. 5.—Celadonite Stalactites.

Stalactitic Agates.

The first layer or layers of chalcedony invariably coat every part of the surface of the celadonite or skin. In an ordinarily formed agate the surface of these layers is smooth; but, where the celadonite invested a rough cavity, the chalcedony is slightly mammillated.

In such agates as contain pendulous threads of celadonite, these are coated by the chalcedony to a thickness equal to that on the sides of the cavity; so that pendulous processes of chalcedony, simulating stalactites in appearance and form, result.

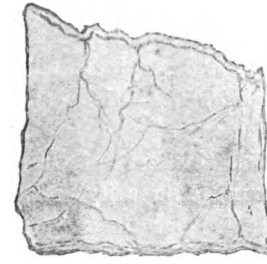

Fig. 6.—Interlacing Celadonite, the Framework.

Should the process of filling of the cavity be completed by any new arrangement of parts, the stalactites come to be imbedded in the substance of these new arrangements. Any difference in the manner in which they are so imbedded alters much the appearance of the agate (figs. 7, 8, and 9).

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Moss Agates.

In manner identical with that which obtains in the formation of stalactitic agates are *moss agates* formed. These may exist as an open network of mutually interlacing tortuous strings, or the continued filling up of the cavity may unite all into a solid mass. In some localities the filaments of moss agates have a dendritic or tufted arrangement; they are then generally brown or yellow in colour.

Structure.

Like malachite, göthite, hæmatite, and all substances deposited from solution upon uneven surfaces, the chalcedonic matter of agates has a double structure, the second of which lies more or less at right angles to the bounding surfaces of the first. There is a surface-enfolding deposition in layers, which successively assumes more and more of a *mammillated* appearance; and a divergent or *radiating acicular* structure, which lies more or less at right angles to the first. This incorporated dual structure is nearly equally manifest when the agate is cut in a direction which cross-sections the layers.

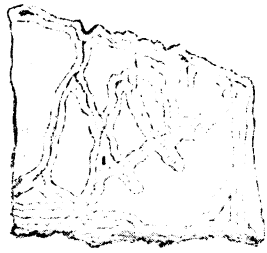

Fig. 7.—First Coating of Chalcedony on Celadonite Filaments.

As the material which forms the acicular structure is much less soluble in alkalies than is the general substance of the chalcedony, and as it is anisotropic, it is probably of the nature of *tridymite*—the general mass being colloidal, and true *chalcedony*.

The thickness of the layers of this latter increases with the amount of impurity in each layer.

So long as the material deposited is of the same nature, the adhesion of the several layers is perfect, and the most facile fracture is along the fibres of the divergent spiculæ.

At the margin of any alteration of material there is much less, sometimes little or no, adhesion, and but a slight shock is sufficient to detach the layers from each other.

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Cacholong Agate.

The substance cacholong (Mongolian, kaschtschilon—*beautiful stone*) is usually classed with the opals, and is of a somewhat mixed composition—one which indicates a small admixture of a zeolite with opal.

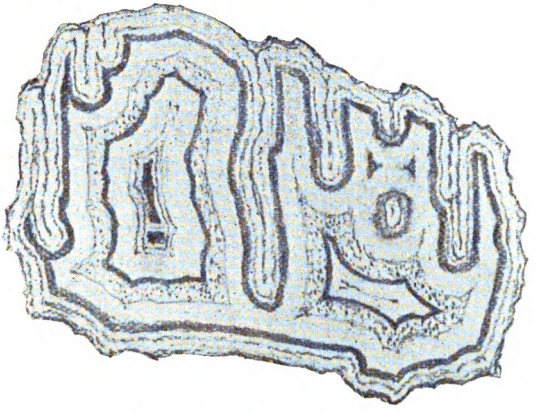

Fig. 8.—Varieties of Agate Building.

The cacholong which forms the white band of Scottish agates consists, however, in far the greater number of cases, of a

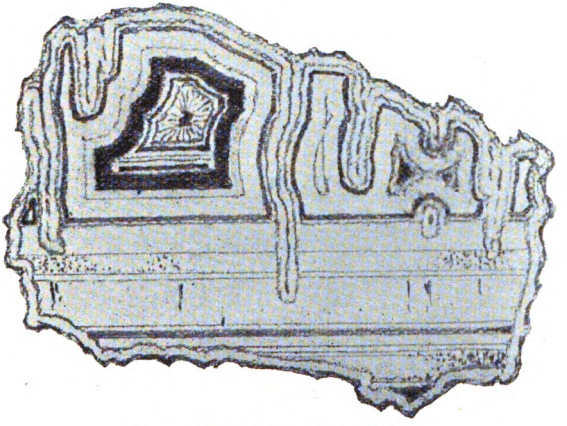

Fig. 9.—Varieties of Agate Building.

substance which, under the microscope, displays a strongly-marked radiating structure (*tridymite ?*) disposed transversely to

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the bands, and penetrating a magma of highly-chromatic opal. This variety is semi-transparent.

An opaque milk-white variety seems composed of chalcedony charged with "quartz nectique." This sometimes adheres to the tongue.

A third very rare variety with a tufted structure may contain a fibrous zeolite.

The cacholong of white onyx is *milk opal;* the loss of its small content of water makes it more or less opaque.

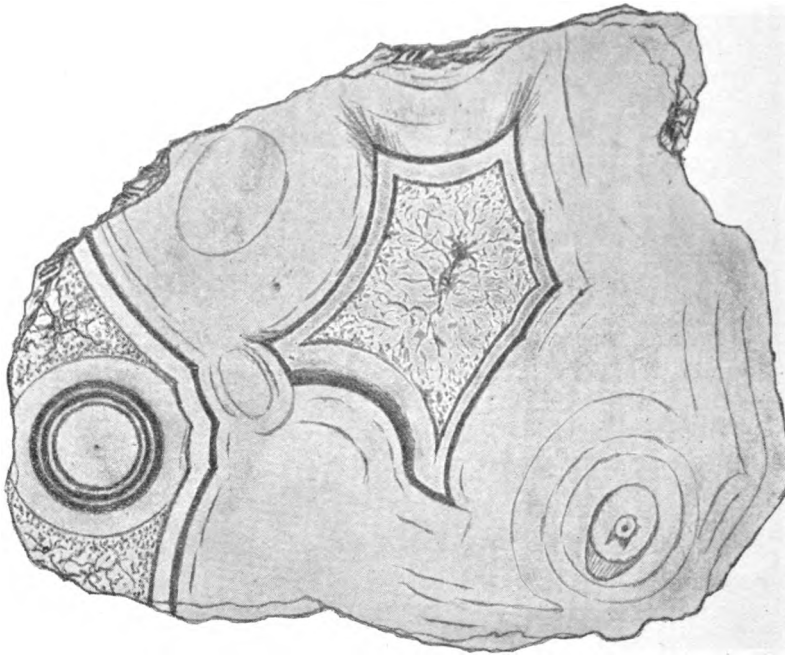

Fig. 10.—Fortification Agate, with Sectioned Stalactites.

Carnelian.

True carnelian, or red-tinted chalcedony, is exceedingly rare in Scotland, the colour of the red-tinted bands of Scottish agates being due to a multitude of spots of a ferruginous silicate, which have segregated out of a stained chalcedony. These red spots are frequently replaced, with amazing suddenness, by others of an equally brilliant yellow, or both will equally

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suddenly disappear—the band which carried them appearing as if bleached.

Fortification Agates.

The mammillated structure which the layers of an agate assume when they line rugose surfaces increases in size with every successive layer, so that towards the central parts of an agate sharp re-entering, but curvilinear, angles lie between these mammillations. Should one or more of the succeeding layers be cacholong or sard, these, taking as it were a cast of such re-entering angles, when cross-sectioned appear with salient projections, and resemble the rectilinear parapets of a fortification (figs. 10 and 11).

Fig. 11.—Fortification Agate

Entrance of Solution.

That the siliceous solution entered uniformly round the whole surface of the druse would seem evident from portions of the skin having been frequently forced into the cavity throughout its whole periphery, and from these having been sheathed in clear chalcedony upon *both sides* of such portions, forming a false moss agate. This envelopment of the intruded skin is either immediate, or the clear chalcedony is seen to invest both the skin and a previously deposited layer of chalcedony, which had, previous to their intrusion, lined the *inner* surface of the disrupted fragments.

The Tube of Escape.

The liquid which holds the chalcedonic material in solution is forced by endosmose through the several layers of chalcedony, along the divergent tridymite fibres. After the deposition of its content of silica, it is forced out of the cavity by the accession of a new supply of chalcedonic solution passing inwards from all sides of the agate. The now de-silicified liquid escapes through one or many tubular openings; these are disposed at every part of the surface-cavity, but very rarely near its base. Frequently this opening is linear, with a false appearance of being a rent; and not infrequently a linear projection on the surface of this agate follows the course of the opening.

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The thickness of each layer of deposited material invariably diminishes as it approaches the "tube of escape." This tube, with the dilatation which frequently occurs thereon, is the last portion of the cavity to be filled; and in that portion which passes

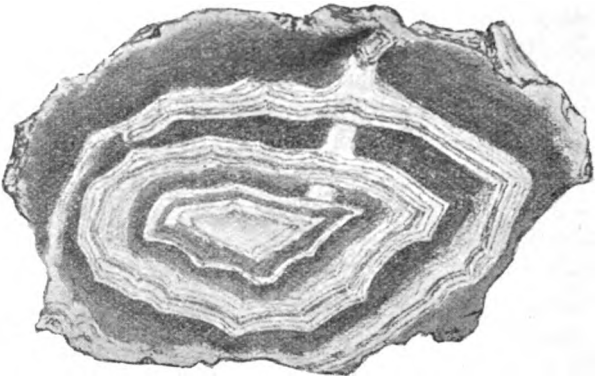

Fig. 12.—Cacholong and Chalcedony Agate, with one Tube for all the Cacholong Layers.

through the outer clear chalcedonic layer, it is of microscopic dimension—almost invisible to the eye—and it most frequently remains open (figs. 12 and 13), and may become a rent.

Dilatation on the Tube.

In almost all cases there occurs on the tube of escape a dilatation of considerable size. This is situated near the point where the tube reaches the earliest deposited layer of chalcedony. It is filled somewhat posteriorly to the centre of the agate, but generally with the same material—quartz. Occasionally it alone contains cacholong, and very rarely it alone contains onyx.

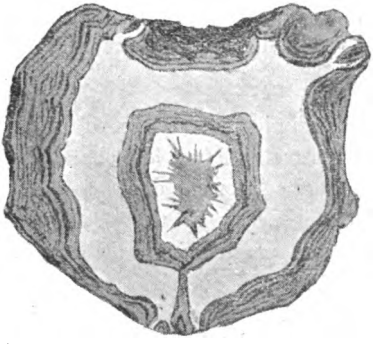

Fig. 13.—Cacholong and Carnelian Agate, with two Tubes for the Cacholong and one for the Carnelian Layers.

No attempt has been made to explain this dilatation, although probably the whole secret of agate formation is

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connected with its presence. It resembles the congestion which takes place when a stream of individuals is arrested at a narrow exit (figs. 14 and 15).

Fig. 14.—Dilatation of the Tube, filled with the same material as the centre: Quartz.

ABNORMAL STRUCTURES.

Onyx.

The adhesion of the layers of deposit of pure chalcedony to one another is so great that gravitation does not interfere appreciably,

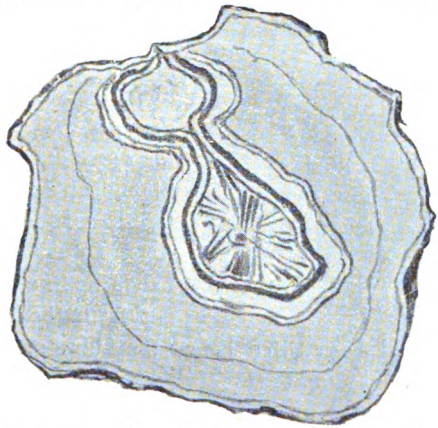

Fig. 15.—Dilatation of the Tube, filled with Cacholong.

or determine any undue thickness of these layers at the lower part of the cavity. The thickness of the layers which form

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so-called "stalactites" is no greater at their pendulous extremities than elsewhere. In the case of others of the materials which go to the formation of agates, however, there is so much feebler an adhesion both to chalcedony and to each other, that gravitation interferes to a marked extent, so that most of the coagulating material is found at the lower part of the cavity, and a zonation or parallel banding of cacholong, sard, opal, quartz, and chalcedony appears—forming horizontal layers or bands in the lower part, or less frequently in the greater part, of the remaining cavity. This banded structure, from a resemblance to the human nail, is termed *onyx*.

The layers of an onyx, especially those consisting of cacholong and opal, are occasionally nearly an inch in thickness; but, however wide, each band is continuous round the whole upper part or "dome" of a cavity, though they are there of *extreme tenuity*. Opal in this acts exceptionally, remaining apparently absolutely as a band at the floor of the cavity. In many chalcedonic druses the dome remains unfilled.

Should purer chalcedonic substance succeed the cessation of onyx formation, the upper part of the cavity is again lined with layers of uniform width, or a second onyx structure may appear at the actual centre (fig. 16: see also fig. 3).

Fig. 16.—Onyx Agate.

Onyx structure is invariably horizontal, and so it *discloses the position which the agate occupied in a rock.* Should an inner, and therefore secondary, deposition of onyx appear in which the bands lie in a position different from the first, it shows that the rock had been tilted before the filling of the druse had been completed.

Plynthoid Onyx.

During the shrinkage which may be supposed to be associated with, or to accompany, the solidification of the chalcedonic matter, and which shrinkage in certain cases may account for the easy

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separability of the layers from one another, it may be seen that, as a general rule, the parallel layers which go to form onyx do not obey the usual law. These layers rend *vertically*, and the material which forms them concretes laterally into, as it were, a series of brick-shaped bodies. The spaces intervening between

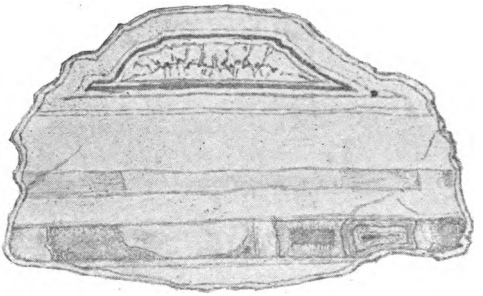

Fig. 17.—Plynthoid Agate.

these, if they are mere rents, are subsequently filled with chalcedony; if they are wide they are either at the time of the concreting filled up with rock crystal, which has separated from the chalcedony or cacholong,—or else they are thereafter plugged with independently-formed agates of more or less rectangular shape (fig. 17—lower part).

Wave Onyx.

In these the various layers have not, in solidifying, been rent asunder by transverse planes of division, but have assumed curvilinear outlines at their fringes. Overlying layers have been deposited successively in the hollows between such fringes, so that this structure, when seen in section, presents an appearance similar to that of tumbling waves or of hummocky ice (fig. 18).

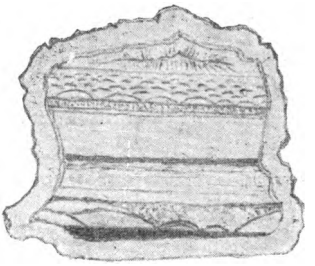

Fig. 18.—Wave Onyx.

Eyed Agates.

Occasionally—but very markedly at certain localities only—after the deposition of the first thin layers of chalcedony, a number of the succeeding layers are not disposed uniformly

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over the inner surface, but are confined to one or more spots, where a slight roughness, or a thickening of the skin, seems to exercise an undue amount of adhesion,—or even of attraction. Around, or over, this spot (or spots) the succeeding layers are, during a brief succession, exclusively deposited — hence assuming a hemispherical form. Cacholong, or carnelian, when present,

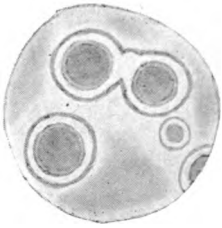

Fig. 19.

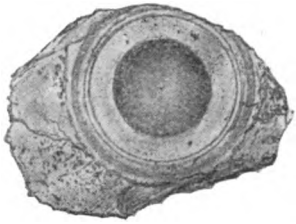

Fig. 20.

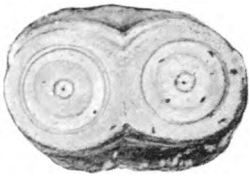

Fig. 21.

Cross Sections of Eyed Agates.

Fig. 22.—Section of Cacholong Eyes.

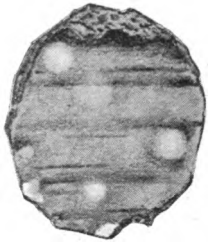

Fig. 23.—Cacholong Eyes, inside Skin of an Inky Onyx.

generally is seen in these hemispherical layers, alternating with layers of chalcedony; so that, upon sectioning, an appearance like that of an eye is disclosed. Such "eyes" occasionally, but rarely, occur on more central layers. Not unfrequently they are, to a considerable extent, formed of an impure fibrous calcite (figs. 19, 20, 21, 22, and 23).

ABNORMAL STRUCTURES IN THE LAYERS.

That the gelatinous chalcedony of the layers is not rigidly solidified immediately upon its separation from the solvent is shown by the concreting at certain spots of substances which may be regarded as having been dissolved in or held in suspension in the chalcedony solution. Through the segregation of these

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certain isolated, and apparently suspended, structures appear in the layers of deposit. Agates exhibiting these are termed discachatæ—oonachatæ—hæmachatæ.

Discachatæ, or Disc-bearing Agates.

The layers of agates very infrequently consist of the *pure* material of the several varieties of silica of which an agate is built up. Very generally there is some admixture—as of chalcedony with opal, or *vice versâ*,—of chalcedony with cacholong, or of chalcedony with a ferruginous silicate.

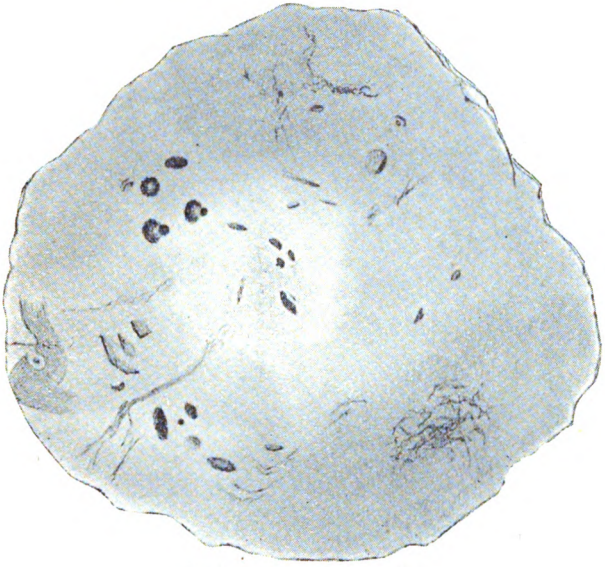

Fig. 24.—Disc-bearing Agate.

When the amount of such admixture exceeds a certain limit there is a concretionary separation of that substance which occurs in *smaller* amount,—and the concretionary forms are characteristic. The clouded milky appearance of some chalcedonic layers, due to uniform diffusion of cacholong, is cleared up as it were, in some parts of the layer, by that substance having been concreted laterally around a spot of roughness, or difference of substance. When this concreting is confined to one layer, one or more opaque milk-white discs result (fig. 24).

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Oonachatæ, or Ovoid-bearing Agates.

There are two varieties of these—chalcedonic, and cacholong. Both result from the concreting of a small portion of one substance which has been suspended in, or mixed with, an excess of another. In both there is the assumption of an egg-like form, but the structure of these is very different.

Such shapes when formed of chalcedony occur in milk opal, and have a fibrous structure which radiates from the centre uniformly in every direction (fig. 25).

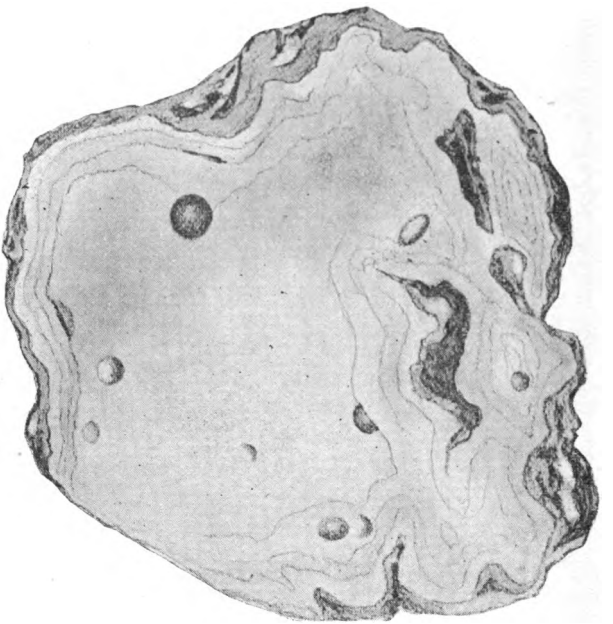

Fig. 25.—Disc-bearing Agate.

When formed of cacholong they occur in chalcedony, and the form results from the superposition of a system of discs (see discachatæ), one over the other, in successive layers. The pre-existence of a disc in a layer of earlier deposition seems to determine the formation of others in superposition. The relative size of these discs increases with successive layers and thereafter again diminishes, so that a solid opaque ovoid suspended in clear chalcedony results. Occasionally each alternately

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succeeding layer is uniformly clear, so that a series of opaque white discs, successively enlarging and then successively diminishing in size, is here presented (fig. 26).

Hæmachatæ,

agates, with blood-red discs,—or with spots, approaching in form more or less to perfect spheres. Such are formed in red-tinted chalcedony in the manner already described in connection with disc-bearing and ovoid-bearing agates. Frequently the ferruginous silicate assumes an annular form, which is merely the periphery of a colourless disc (figs. 27 and 28).

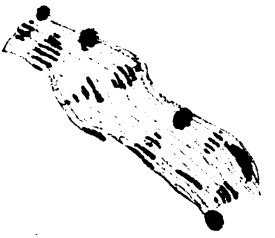

Fig. 26.—Discachatæ and Oonachatæ.

Hæma-Ovoid Agates,

result from one abnormal structure being present within another. The milky material, segregated apart to form the discs (whose superposition in varying size results in an ovoidal structure of cacholong), contains within itself red colouring matter, which has separated in each disc into a series of rings which are made up of red discoidal spots. As these rings of dots are at the same distance from the circumference of the discs, it results that each

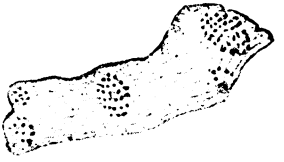

Fig. 27.—Hæmachatæ Ovoids.

Fig. 28.—Hæma-Ovoid Rings.

ovule displays upon *longitudinal* section either a single dot ring, or a system of red oval dot rings,—as well as either a single dot ring, or a system of circular dot rings upon *cross* section (fig. 28).

Red or carnelian agates are frequently sprinkled throughout with lustrous spheres which resemble drops of yellow oil. As these show no varying colours in the polariscope they cannot be opal.

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CRACKS IN AGATES.

First.—The rock may have been rent—dislocated by a lateral shift—and re-cemented, so as again to contain a tight cavity, before the endosmotic filling of the latter. In such cases the layers of deposit in the agate follow the dislocation of the rock.

Second.—The rock, with included agate, may have been rent with dislodgement of parts, and these may have been thereafter re-cemented either by a new access of chalcedony, or of calcite.

Again, the rock and agate may have been shattered, with dislocation and almost inversion of fragments—with extrusion of some—or intrusion of the matrix or of jasper, and re-cementation by clear vein-like chalcedony. Very rarely when the fracture occurred before the cavity of the agate was entirely filled, the subsequent layers folded into the rent and effected a re-union.

At certain localities the agates are frequently divided by a straight rent, and one portion entirely removed.

Recent open cracks are probably due to frost.

ALTERATIONS OF COLOUR.

Agates may be naturally or artificially stained. They may also be bleached.

Open cracks frequently convey ferruginous waters which stain agates elsewhere colourless,—or, carbonated waters which bleach red-tinted stones.

The loss of the small amount of water present in chalcedony renders its translucent structure white and opaque. The loss of the large amount present in opal renders it white, opaque, and granular (*quartz nectique*); and the removal of this loose powder by water splits up an onyx into plates of chalcedony which exhibit an ovoidal or micro-mammillated surface.

The appearance of the commoner varieties of agates may be improved by artificial staining. Chalcedony absorbs staining liquids. Cacholong, opal, and quartz do not. Colourless chalcedony may be stained dark-brown by being heated in a strong solution of honey, which is after-carbonised in its pores by sulphuric acid. The stain penetrates to about the fortieth of an inch.

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MOCHA AGATES.

Mochas are agates between the layers of which water—carrying manganesian or ferruginous matters in a state of minute division—has penetrated. Upon the evaporation of the water, the intruded solids have been deposited in an arborescent form. More rarely this deposition is in cracks.

JASP AGATES.

Stalactites of celadonite, or other "skin-material," are invested by a thick layer of colourless, or by jasperous, chalcedony. This chalcedony holds, as it were in suspension, multitudes of spheres of carnelian. This structure-within-structure shows that the deposited layers of chalcedony do not, immediately after their

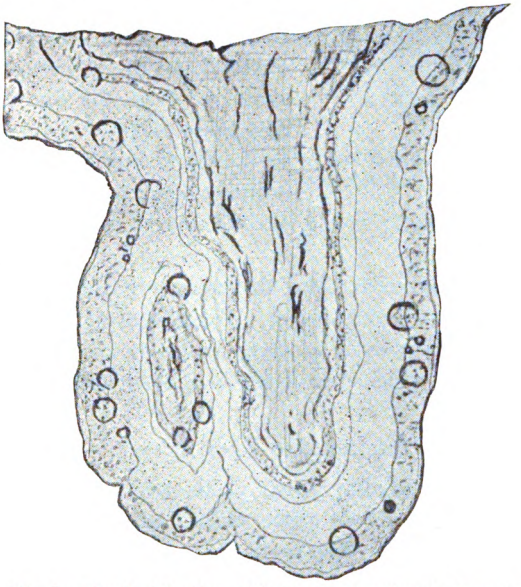

Fig. 29.—Longitudinal Section of Stalactite Structure in Jasp Agate, Ayrshire.

deposition, concrete into a solid, but allow of motion sufficient for the formation of an independent structure within their substance. Anomalous as such an arrangement may appear, the structure of these spheres is still more so, as many of them show that their colouring matter is disposed so as to simulate the whorls of a

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volute. They thus occasionally present a certain resemblance to minute ammonites. Jasp agates are usually vein agates (figs. 29 and 30).

Stalactitic Jasp Agate.

In this, the more common variety of jasp agate, the stalactites which impart the prevailing characteristic are disposed in the same nearly-parallel arrangement which is seen in ordinary stalactitic agates—being pendulous from the upper part of the vein. In many cases where there has been an excess of celadonite or other basement material of these stalactites there is a greater or less approach to the structure of moss agate. When the fibrillæ which determine this structure are separated to any great extent, the ordinary agate arrangement of successive layers occurs; even a central mass of quartz occasionally presenting itself.

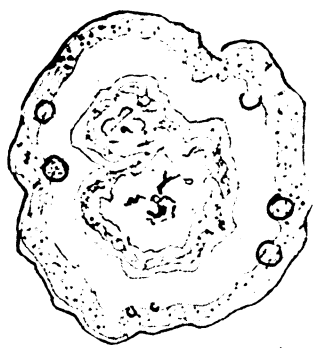

Fig. 30.—Transverse Section of Stalactite Structure of Jasp Agate, Ayrshire.

When, again, the moss agate structure is unusually close, there is an approach to ordinary jasper. When central vacuities occur in this, the parts margining these vacuities are sheathed by a layer of carnelian—the centre being here filled with a manganesian calcite.

Brick-shaped Jasp Agate.

At the Ayrshire locality which yields jasp agate, a prevailing structure is that of a vein agate which has been cross-rent into brick-shaped segments. The rents which intersect these veins are filled with impure manganesian dolomite, which is the lining material of the veins themselves. The coagulating silica which fills these rectangular spaces has thereafter concreted so as to line the sides with layers of brilliant red, yellow, pink, and white colours—these colours being usually deposited in a system of minute spots. Thereafter these *brick-shaped* structures have themselves frequently been rent—these secondary rents being also filled by a dolomitic paste.

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True jasper very rarely forms layers in an agate: when it occurs it invariably is confined to a small portion of the periphery, being deposited somewhat after the manner of an "eye."

Note.—The accomplished author of the preceding paper, Dr. Heddle, died, after a long illness, at St. Andrews, on the 19th November, 1897. He had gone over a first proof, and had finished most of the drawings to illustrate it before his death, but it had to be held over from the previous part of the *Transactions*. Ed., 1900.

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No. XIII.—On the Old Volcanic Rocks of the Island of Arran. By William Gunn, F.G.S., *of H.M. Geological Survey.* Communicated by permission of the Director-General.

[Read 31st May, 1899.]

An interesting discovery of a volcanic series in the Lower Old Red Sandstone of the Island of Arran was made last year, and as this increases the number of the series to five, and there seems the probability that the tale is now completed, it may be desirable to give a sketch of them as a whole, along with a more detailed account of the most recent.

Two of these sets of old volcanic rocks are contemporaneous with different divisions of the Old Red Sandstone, while three occur in the Carboniferous formation.

1. The oldest of the five, and the last to be discovered, is found on the west side of the island in the lowest division of the Old Red Sandstone. This formation, as exposed on the coast near the mouth of the Iorsa Water, is largely composed of bands of conglomerate, and there are fine sections to be seen in the old sea cliffs, and on the shore S.E. of Dougrie. The coarse quartzite conglomerates alternate with red and purple sandstones, and the total thickness must be several thousand feet. The dip is at high angles to S.S.W., and they strike inland and eastwards, where the dip gradually changes to S.E. The principal mass of conglomerate rises into a broken ridge, and seems more than usually thick in the hill called Garbh Thorr, near Monyquil.

Now it is to the north of this marked band of coarse conglomerate that the contemporaneous trap occurs, and as the dip is to the S., it, of course, underlies the conglomerate. The best section of the old lava is in the Auchencar Burn, about 70 yards E. of the moor dyke, and E. of the hamlet of Auchencar, and here a thickness of from 50 to 60 feet of trap is exposed—fine-grained below and amygdaloidal above. The band crosses the burn diagonally, and being nearly vertical, occupies but a narrow space when followed eastwards. It is often covered by glacial drift, but still there are traces in

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several places, and unmistakable outcrops of it occur N. of a hill called Baniorlach, and N.W. of Garbh Thorr, where it appears to be thicker than in the Auchencar Burn. This latter place is about 2½ miles to the east of the outcrop in the Auchencar Burn. The trap seems generally to be coarsely amygdaloidal, and of an andesitic character, but the lower part is often fine-grained, and seems more basic than the rest. No trace of any volcanic tuff was observed. The beds which underlie the trap consist principally of fine-grained flaggy sandstones. In the conglomerates which overlie the trap pebbles of an andesitic rock occur, which are probably derived from the old lava below. The volcanic series has most likely been extensively denuded both before and during the formation of the conglomerates.

2. On the eastern side of the island another set of volcanic rocks occurs in the Old Red Sandstone at a much higher horizon than those just described; in fact, several thousand feet higher up in the formation. They are to be found on the hillside N. of North Glen Sannox, and seem certainly to lie at the base of the Upper Old Red Sandstone. The area in which the volcanic intercalations occur is much faulted, and only a part has been mapped in detail, but the position of the interbedded igneous rocks is quite clear. The Old Red Sandstone consists of three distinct members, the lowest of which is made up of coarse well-rounded quartzite conglomerates, alternating with sandstones and purple mudstones. Above this, and apparently unconformable to it, is a middle series of light-coloured conglomerates and sandstones, the pebbles in which are mainly of quartz. Finally comes an upper series of red sandstones and conglomerates, which occupy nearly the whole of the coast section, and it is this series which has generally been taken as the typical Old Red Sandstone of the island. The volcanic series is intercalated between the middle and upper divisions given above, and may be seen in several places between the shepherd's house at North Sannox, and Laggan. It consists mainly of old lava-beds of a dull reddish or purplish colour, often soft, and in places much decomposed. It seems basic in character. A specimen from near the Fallen Rocks, examined by Mr. Teall, was found to be too much altered

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for precise determination, but was probably a basalt originally. These volcanic rocks do not occur on the coast.

3. We now arrive at the lowest of the three sets of volcanic rocks in the Carboniferous formation, which is so well known as to need no particular description. It has long been known to occupy large areas in Renfrewshire and Ayrshire E. of the Clyde; it composes nearly all the Little Cumbrae, and a good deal of the southern part of Bute. In Arran its old lava-beds crop out on the eastern shore near Laggan, and here some of the finer volcanic tuffs yielded to Mr. Wünsch the fossil trees and plants so long ago described by Professor Williamson. The same volcanic series is found again N. of Corrie, a somewhat steeply dipping mass of basic lavas and agglomerates, some 300 or 400 feet thick. Here, however, its contemporaneous and intercalated character has not always been recognised, for it has sometimes been spoken of as a dyke. Inland there are good sections of this old trap in the streams W. of Corrie and N. of Maol Donn. It forms an integral part of the thin band of high-dipping Carboniferous rocks to be traced in the woods behind Brodick Castle, and on the S. side of Glen Shurag; and onwards to near the centre of the island, in a broken way by the heads of Glen Dubh, Benlister Glen, and the northern branch of the Sliddery Water; and it is the last part of the Carboniferous formation to disappear under the Newer Red rocks near Cnoc a Chapuill. In many parts of Scotland this old set of volcanic rocks is nearly on the boundary between the Lower Carboniferous and the Upper Old Red rocks.

4. Another and thinner volcanic series in the Carboniferous formation, on the horizon of the upper limestones, has been found in the Clachland Burn, N. of Brodick Castle, and in the woods to the S.W. It is from 10 to 25 feet in thickness, a red series of lava and tuffs, in character very like the one just described which occurs near the base of the Carboniferous formation.

5. The fifth and most recent set of volcanic rocks to be now described lies between Lamlash and Lag, and was first generally examined in the year 1894. In the Report of the Geological Survey for that year reference was made to the discovery in

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Arran of a new volcanic series, apparently intercalated in the Newer Red sandstones of Sliddery Water Head, specimens being said to resemble the lavas which occur at the base of the Permian rocks of Ayrshire and Nithsdale. The group consists of dull-red slaggy lavas and red tuffs, the latter preponderating, and varying from fine muds to coarse agglomerates. They include two bands of sandstone and shale, among the debris of which was found a large and fine specimen of *Stigmaria* pronounced by Mr. Kidston to be of either Carboniferous or Permian age.

Subsequently it occurred to the writer that this volcanic series might possibly be a repetition of that of Lower Carboniferous age, which is seen about a mile to the northward, brought up again in some inexplicable way, though the sections in the two localities are very different. Unfortunately these volcanic rocks are so nearly encompassed by intrusive igneous masses that their relations to the surrounding sandstones are not free from doubt. It was not till the spring of 1897 that these rocks were examined by the fossil-collector of the Survey, Mr. Macconochie, when a thorough search was made in the rocks of the southern part of Arran, and though nothing was found to reward his search in the Newer Red sandstone, the shales interbedded with the volcanic series of Sliddery Water Head yielded plants, shells, and fish remains.

These specimens were examined by my colleague, Mr. Peach, who was at once struck with their Coal-measure aspect, chiefly due to the presence of *Carbinicola* (*Anthracosia*) *acuta*, and another species of *Anthracosia*, forms which are not known to occur in strata lower than the Millstone Grit, and are much more commonly met with in the Coal-measures. The fish-fragments were referred to Dr. Traquair, who was of opinion that they also had a Coal-measure facies, though they did not afford sufficient evidence to make their horizon quite certain. A second collection was made by Messrs. Macconochie and Tait from the same strata, and Mr. Peach accompanied me on another visit to the ground, when the fossiliferous bands were carefully examined. The result of these investigations was to leave no doubt in our minds that the rocks in question occupy the same horizon as those overlying the highest Car-

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boniferous volcanic zone in the Fenwick Water, near Kilmarnock, viz., the strata associated with the "mussel bands" which overlie the "slaty band ironstone" of Dalmellington, Lugar, and other parts of Ayrshire. This "slaty band ironstone" is the datum-line used by the Geological Survey as the base of the Coal-measures in Scotland. It may be mentioned that just previous to our inspection of these beds in Arran Mr. Peach and I visited Mauchline and Kilmarnock to make a comparison of the rocks in that district with those in Arran.*

I shall now proceed to give a somewhat detailed account of the structure of the ground where the fossils occur and particulars of the different sections.

The newer † volcanic series of Sliddery Water Head lies nearly 4 miles to the south-west of Lamlash Pier. It can easily be reached by the steep Ross road, up the Monamore Glen, which at the summit and water-shed is 933 feet above sea-level. Looking southward from milestone No. 9 the observer sees opposite to him a green hillside, sloping to the N.W., which is featureless except for two projecting nearly horizontal bands, the lower of which is formed by an intrusive felsite sheet, and the upper by a bed of felspathic grit intercalated in the volcanic rocks. The road at this point skirts the lavas and tuffs for about half a mile, but as nothing can be seen of these rocks to the N. of the main stream, it is necessary to leave the road and go southward. The area over which they can be observed is rudely triangular, stretching from N.E. to S.W. for nearly $\frac{3}{4}$ of a mile, with a breadth of 600 yards at the widest part, but they may extend in a narrow band to the N.E. some 200 or 300 yards farther than the most northerly points noticed, and they may also occupy the drift-covered ground between the road and the main stream, and thus the breadth may be 100 yards more.

The rocks, for the most part tinged deep red or purple, are

* A complete list of the fossils obtained at Sliddery Water Head is appended.

† So named to distinguish it from the older volcanic series above referred to as occurring about a mile to the north-west in a locality which may also be called Sliddery Water Head, for it embraces the head of the most northerly branches of the Sliddery, which are also the largest. This older volcanic series is the lowest that occurs in the Carboniferous formation. (No. 3 in order of description. See page 176.)

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arranged in the form of an anticline, the axis of which runs E.N.E. and W.S.W. Only the southern side, however, of this anticline is well exposed, the opposite one being much obscured by glacial drift. The principal sections are found in three parallel small nameless branches of the main stream of the Sliddery Water, and here called for reference *Burns A.*, *B.*, and *C.*, which rise in the higher ground to the S. and run north-westward across the area. The longest of these streams, *Burn C.*, rises W. of Cnoc Dubh; the next, *Burn B.*, $\frac{1}{4}$ of a mile to the E., is not shown on the 1-inch map; and *Burn A.* is the most easterly. Sections are also to be obtained in several still smaller parallel branch streams, and in the main stream which runs parallel to the road, more especially in that part of it just above and just below the foot of *Burn C.*

As there is considerable variation in the different sections a few of them may here be separately described. The observer must be prepared to find quite a number of intrusions of igneous rocks of various forms and kinds, and of a much later date, which often come into the most interesting parts of sections in a very tantalising manner, and obscure what would otherwise have been clear. The general stratigraphical succession in this area is shown in descending order in the following table:—

Base of Newer Red sandstone and conglomerate (? Permian).

Lavas, very slaggy and amygdaloidal, with occasional ashy bands.

Coarse felspathic grit.

Shales and ironstone bands with an intrusive sheet of felsite.

Flaggy sandstones and shales passing westwards into fine red volcanic mudstones. (This is the band which has yielded most of the organic remains.)

Alternations of fine red volcanic mudstone and tuffs, with coarse volcanic ash and ashy sandstones, and sometimes apparently beds of lava.

The base of the series is nowhere observed, so that nothing is yet known of the rocks immediately below it.

It may be remarked that in consequence of the extensive

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alteration of these rocks it is by no means easy to distinguish, in hand specimens, between the lavas or massive rocks, and the tuffs or tufaceous sediments.

Burn A.—In this stream, which affords the most easterly exposure, the volcanic rocks cannot occupy more than 150 yards of the lower part of its course, and as about one-half of this distance is obscured by drift, the section is a very small one, and the exposure is not good. Beds of purplish-red tuff occur, and seem to pass into a more massive rock in places. The dip is down stream, or towards W.N.W., at a low angle. Higher up the burn these rocks are abruptly truncated by a coarse mass of intrusive dolerite, much decomposed, which here bounds the volcanic series on the east. To the S.W., between this burn and the next, there crops out on the hill-side a massive red rock, parts of which are very puzzling. In some places it looks like an undoubted tuff; in others it presents no fragmental material, and then resembles a fine-grained lava.

Burn B.—This stream, though inserted on the six-inch map, is omitted from the one-inch sheet. At its junction with the main stream, about 230 yards S.W. of the foot of *Burn A.*, a mass of pale-yellowish intrusive felsite occupies the bed of the main stream for 100 yards or so. Into this felsite dykes of basalt have been intruded, while dykes of a similar kind, ranging from N.N.E. to E.N.E., and intrusive in the volcanic rocks in the lower part of *Burn B.*, are fairly abundant. The first rock in this stream above the felsite is an undoubted tuff, some of it coarse in texture, which dips northward at, perhaps, 20 deg., the angle lessening to about 10 deg. higher up, when a massive, hard, close-grained rock appears, like that to the N.E., lately described. About 150 yards further up an undoubted slaggy lava occurs, and near it a beautifully banded intrusive felsite dyke crosses the stream side-by-side with a basalt dyke. Above this point the rocks become horizontal, and soon incline in the opposite direction, towards the S.E., until the intercalated beds of shale and sandstone are reached. Among the gently-dipping beds about the waterfall bands or beds of fine red mud and shale, probably of volcanic origin, may be seen, alternating with coarse tuff and also with rocks

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composed of mingled volcanic and sedimentary material, the volcanic matter seeming generally to predominate.

The most important part of the section is reached 250 yards up the stream from the foot, where the beds of fossilferous shale are found below, and partly included in, an intrusive sheet of pale-coloured felsite. As far as can be made out, the succession of strata is as follows in descending order:—

1. Shale with bands of ironstone, nearly included in the felsite. *Carbonicola* (*Anthracosia*) abundant.
2. Sandstone white, flaggy, and quartzose, with *Stigmaria*, 12 to 15 feet thick.
3. Shale with ironstone bands, full of shells in places. 8 to 10 feet thick.
4. A thin grey sheet of (? intrusive) basic rock, amygdaloidal at top, seen on both sides of the burn. About 2 feet thick.
5. Shale reddish, and dark-coloured, some of it towards the base probably slightly tufaceous; it contains some nodules of ironstone, and seems to pass down into fine red tufaceous muds. 8 to 10 feet thick.

These strata dip S.E. at an angle of 12 deg.

It is from the upper part of No. 3 of the foregoing section that most of the fossils have been obtained. Some thin bands are crowded with specimens of *Carbonicola*, and the same horizon yields plants and various species of fish. In all there have been obtained 7 species of fish and 2 of *Carbonicola* (*acuta* and *robusta*), which appear to be characteristic of the Upper Carboniferous formations of Scotland, *i.e.*, of horizons above the highest marine limestones. They probably indicate that the beds containing them belong to the Lower Coal-measures. On the other hand, the only plant in the collection which could be identified specifically by Mr. Kidston is *Lepidodendron Veltheimianum*, and it has never yet been found above the Carboniferous limestone.

Burn B.—The section here above the felsite sheet is very unsatisfactory. Nothing can be observed for some distance, and just below the gorge, which commences 50 yards above the felsite, there only appears a poor section in micaceous shale and sandstone, which underlie a strong band of light-

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grey, rather coarse, felspathic grit. This band, which seems to be 20 to 30 feet thick, does not appear in the burn, but forms a conspicuous feature on either side, especially on the N.E., where it can be traced for 250 yards, with a S.E. dip. Together with most of the rocks previously described, it is cut off on the E. side by an intrusive mass of felsite. Above the grit-band comes a mass of slaggy lava, of which there are only few and poor sections, but as it is traversed by a distinct feature along the middle, it is not improbably divided there by a band of tuff. As the burn at this place is occupied by an interesting composite dyke, little of the lava is seen, and nothing of the grit below it. The dyke has a central mass of quartz felsite, with thin basic bands on the sides. The S.E. boundary of this volcanic series appears to be a natural one; a feature of the ground strewn with blocks of a whitish sandstone probably marks the oncoming of the Newer Red rocks above the volcanic zones. The latter seem to occupy a peat-covered flat S.W. of the burn, but there are no satisfactory sections in that direction till we arrive at *Burn C.*

Burn C.—The most interesting part of the section exposed in this burn lies about ¼ of a mile above the main stream, where the lava bed or uppermost member of the volcanic series is well displayed, and its relations to the overlying rocks are presented much more distinctly than in *Burn B.* The Newer Red rocks, here thick-bedded yellow sandstones, dip southwards at angles of 15°. Their junction with the lava cannot be observed, owing to the intervention of a felsite dyke just at the desired spot. The slaggy lava is probably about 30 feet thick, apparently much thinner than about *Burn B.* The upper grit and shale band which succeeds below, may be likewise only about 30 feet in thickness. A fault here ranges along the burn, throwing down the S.W. side about 30 feet. The overlying sandstones on the W. are thrown against the lava on the E., and the latter on the W. is opposed to the Carboniferous shale and sandstone on the E. On the W. side, the junction of the Newer Red sandstone with the underlying volcanic series is hidden by debris and vegetation. The dip of the Carboniferous shale on the E. side is to the S.S.W. at as much as 25°, while that of the overlying Newer Red rocks

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higher up the stream is only 15°, but, as these places are some distance apart, the difference in the amount of dip can hardly be taken as a satisfactory proof of unconformability.

The purple and dark shales yield *Stigmaria* fragments, and from a 1-inch ironstone band in them there was obtained by the fossil-collector a small shell (a species of *Myalina?*). Below these shales lies the thick sheet of intrusive felsite as in *Burn B.*, but the fossiliferous shales and sandstones of that stream are here represented by an unfossiliferous mass of fine red shale and volcanic mudstone. These are at first nearly horizontal, but they soon roll over, and the dip is then down stream, to W.N.W., at first gentle, but soon afterwards at a high angle. The purple ash in the lower part of the stream seems in some places nearly vertical, but the section is much confused by dykes of intrusive igneous rock which are a marked feature at the foot of the burn, and in the main stream adjacent, where massive purple and red tuffs and breccias are well exposed above its junction with *Burn C.*, the rock in some places being fine-grained with no apparent fragments. The same kind of rock, seen also below the foot of *Burn C.*, apparently with a dip to the W., is on the whole very irregular, and seems in some places quite vertical. It may be that the rocks here form part of a volcanic neck, and that the irregular and sometimes apparently vertical dip has nothing to do with any subsequent disturbance of the district, but is due to the arrangement of the fragmental material in the chimney of the vent. Farther down the stream the rocks are cut off by an intrusive mass of a basic or intermediate character, which forms the boundary of the volcanic series all along the N.W. side.

The sheet of lava, or uppermost member of the volcanic series, to the W. of *Burn C.*, can be noticed at intervals nearly up to the place where the whole is cut off by the intrusive basalt, but it seems to be very thin and may eventually die out. Except a poor section in a small branch stream 100 yards west of *Burn C.*, the sandstone and shale below the lava are not seen again. Probably they die out or become so mixed with volcanic material as not to be recognisable. The intrusive felsite band can be traced, however, and

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towards the western extremity it approaches near to the lava. It is evident from the course of the overlying conglomerate that the beds at this end turn over to the N., and run down against the intrusive basalt. This locality is about 600 yards S.W. of the foot of *Burn C.* A good section in undoubted ash occurs 150 yards N.E. from this western edge, in a small burn. In small streams and in drains volcanic rock is proved to occur everywhere between this point and *Burn C.*, except where there are numerous intrusions. The exposures, however, are small and unsatisfactory; for sometimes the volcanic rock is massive and fine-grained, and seems to be lava, though generally it appears to be a fine tuff. In ground so much obscured there are doubtless many more intrusive masses in the form of dykes, sills, and bosses, than are exposed at the surface. In many cases a detached knob of igneous rock may protrude where it is not possible to ascertain its limits, and there must be many intrusions not exposed at all, so numerous are they where one gets a good section.

As these intrusive rocks in the area belong to a different and more recent date than the volcanic rocks, it is not the object of this paper to describe them, but some that come into the more important sections have been mentioned.

The volcanic series of Sliddery Water Head is thus seen to be bounded by an intrusive basic mass on its N.W. side. On the E. it is bounded by intrusive masses of dolerite and felsite, except perhaps for a short distance immediately S. of the road, where glacial drift obscures everything. Only along its southern border, therefore, can anything be learnt about its relation to the overlying sedimentary rocks. These succeed to the S., and are presumed to come on unconformably, but not from data gathered directly in this area, where the evidence, as already stated, is not conclusive. When the boundary is traced westward the overlying rock is found to be a quartzose conglomerate, and not a sandstone as in *Burn B.* and *Burn C.*, but irregularities of this nature are common enough in some rocks which are perfectly conformable to one another. It might be argued that the thinning westwards (or dying out) of the lava-sheet, at the top of the series, is due to denudation before the deposition of the Newer Red rocks,

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were it not that both the groups of sandstone and shale intercalated in the volcanic rocks thin away in the same manner.

I have ascertained, however, that an unconformability undoubtedly separates the two formations—Newer Red and Carboniferous—and have traced the boundary over a large area. In the Newer Red conglomerates near the Cock of Arran the pebbles and fragments contain Carboniferous limestone fossils derived from the underlying formation, as was shown many years ago by Mr. James Thompson. Besides, the upper formation at Sliddery is resting on rocks of Lower Coal-measure age, while a mile away to the N.W. the same formation is reposing on strata several hundred feet below, and lower than the horizon of the Corrie limestone.

The position of this volcanic series here is not easy of explanation, nor is its relation to the Lower Carboniferous volcanic series, found more than a mile to the N.W., at all clear. Its N.W. boundary of intrusive rock seems to have come up along a line of fault, which has a downthrow to the N.W., for the volcanic series on that side in the main stream, and to the S.W. of it, apparently comes to an abrupt termination. The boundary seems too straight to be merely an unconformable one, and the intrusive rock perhaps would hardly have come up just along such a boundary. There must also be a large fault somewhere near the E. boundary of the series, throwing down to the E., but there is uncertainty about its exact position, which is hidden by intrusive rocks and glacial drifts. This fault may be the continuation of the large one in Benlister Glen, which throws the Newer Red formation against the Carboniferous.

To account for the fact that the Newer Red rocks are here reposing on beds of Coal-measure age, while to the N.W., a mile away, they rest on Lower Carboniferous rocks, it must be supposed that in the intermediate area the unconformability between the two formations is much more decided than it has been found to be elsewhere in the island, or that there is concealed a post-Carboniferous fault which threw down these higher rocks (Coal-measures) against the Carboniferous limestone series before the deposition of the Newer Red rocks.

Before quitting the description of the rocks of Sliddery

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Water Head some petrological notes regarding their volcanic rocks may be inserted. Reference has already been made to the fact that, associated with the Lower Coal-measures of Ayrshire, or lying immediately below them, a series of tuffs and lava-flows occurs in about the same position as the Sliddery Water Head series is presumed to occupy.* The lavas of Sliddery Water Head have been so much altered, and are generally so much decomposed, that it is difficult to decide as to their exact original character, but the evidence from microscopic examination favours the view that they are olivine basalts of andesitic structure. A specimen from the top of the series in *Burn C.* is thus reported on by Professor G. A. J. Cole, who examined these rocks for the Survey:—"Rock of andesitic lava type, but with the prominent ferro-magnesian constituent blackened on its edges and practically destroyed in its interior. . . . Some sections make it probable that the altered mineral represents an olivine poor in magnesia and fairly rich in iron. . . . The scoriaceous ground-mass consists of plagioclase felspars emerging from the original glass, not sharply developed, and accompanied by ferruginous granules, probably representing pyroxene. The rock is, I think, more basic than its general structure suggests. . . ."

Another specimen, from *Burn B.*, is described by Professor Cole:—"Similar to the last, scoriaceous to amygdaloidal in the mass, with the aspect of a lava. The ferro-magnesian minerals are best observed in the slice by reflected light, but are much 'rusted' by the formation of red iron-oxides. The rock has a 'porphyrite' character, with rather better traces of an original glass among the plagioclase rods of the ground-mass that are seen in the last. . . . I believe it is an olivine basalt of andesitic type greatly altered and oxidised."

The tuffs are often mixed with ordinary sedimentary material, decomposed lapilli deeply stained with ferric oxide representing the volcanic portion, and grains of quartz the ordinary sediment. A specimen from *Burn B.* at the waterfall is described by Professor Cole as "a gritty ash, with fragments of basic lavas and abundant quartz grains." The

* Specimens of these rocks have been sliced for comparison with the slides prepared from the Arran rocks.

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following is his description of a coarse ash or breccia from the main stream below the foot of *Burn C.*:—"Tuff. Fragments of lithoidal basic lavas (in part amygdaloidal and altered olivine basalt), together with lumps of a *metamorphic quartzite* and abundant quartz grains derived from a similar rock. The quartzite has fluid cavities grouped in bands which are continuous from grain to grain. This mingling of gritty matter and truly igneous ejecta recalls the Arenig grits (Garth grits) of the ironstone horizon on Rhobell-fawr, North Wales."

For the sake of comparison with the Coal-measure volcanic series of Arran some petrological notes are here given from Professor Cole's report on specimens from the corresponding Ayrshire series in Fenwick Water, Kilmarnock:—"(7744). *Coarse basalt* (in altered 'diabase' condition). Fresh labradorite felspar, pale pyroxene (augite) developed porphyritically, and also as small granules in the ground. One or two colourless pseudomorphs after olivine. There is a residual glass, now in the green palagonite or 'hullite' condition. Its original crystallites are only dimly seen in some of the less altered browner areas." "(7749). Fine-grained clayed ash, with nodular materials which have arisen in the ash itself, and which sometimes envelope its constituents in concentric coats."

While Messrs. Macconochie and Tait were collecting in Arran they succeeded in obtaining fossils from a number of other scattered localities in the eastern part of the island, which prove the existence of true Coal-measures over a much wider area than had been at first supposed. It is now known that small patches of these rocks occur in the following localities:—Near the Cock; in Lochrim Burn, Corrie; at Maol Donn; and in the Merkland Burn, Brodick. It has been further ascertained that a narrow strip of Coal-measures also occurs in a much-faulted area in the bed of the Benlister Burn, about 2¼ miles W. of Lamlash. From this locality the fossil-collectors obtained both plants and shells of Coal-measure type.

A complete list of all the fossils obtained from Sliddery Water Head is appended. As lists of the Coal-measure flora and fauna from the other localities are rather foreign to the

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title of this paper I do not give them here, but it may interest the members of the Society to have those from one of them.

LIST OF FOSSILS.*

From Cock of Arran shore, 20 yards S. of base of Newer Red rocks.

PLANTÆ. (Named by Mr. Kidston.)

Mariopteris muricata, Schl.
Neuropteris gigantea, Sternb.
,, sp.
Calamites, cf. *varians*, Sternb.
,, *ramosus*, Artis.
,, sp.
Sphenophyllum myriophyllum, Crèpin.
,, sp.
Cordaites principalis, Germar, sp.

From the Lower Coal-measures of Sliddery Water Head.

PLANTÆ. (Named by Mr. Kidston.)

From *Burn C.*
Stigmaria.

From *Burn B.*
Lepidodendron Veltheimianum, Sternb.
Lepidostrobus, sp.
Stigmaria—abundant.
Calamites, sp.?

MOLLUSCA. (Named by Mr. Peach.)

From *Burn B.*
Carbonicola (*Anthracosia*) *acuta*, Sow.
,, ,, *robusta*, Sow.
and another undetermined species.

From *Burn C.*
Myalina? Small species in thin band of red ironstone.

PISCES. (Named by Dr. Traquair, who has supplied the following notes regarding them):—

"The accurate specific determination of the fish-remains from Sliddery in Arran is not easy, seeing that they consist only of isolated teeth and scales, and are, moreover, not in the best state of preservation."

From *Burn B.*
Diplodus, sp., teeth.
Pleuroplax, sp., teeth.

* Last year a further collection from the rocks of Sliddery Water Head was made by Mr. Tait. Plants of exclusively Upper Carboniferous species were found in *Burn B.* above the position of those previously collected; and the ashy beds at the waterfall yielded plants which are all of a Lower Carboniferous type. This last locality is below the beds enumerated in the section on page 181. Particulars of these new discoveries will appear in the forthcoming Report of the Geological Survey for 1899. (February, 1900.)

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Helodus, sp., teeth.
Megalichthys, sp., teeth and scales.
Rhizodopsis, sp., scales.
Strepsodus sauroides, (Binney), teeth.
Platysomus parvulus, (Young), scales.

"The two to which I have attached specific names are certainly Upper Carboniferous species; as regards the others, though the genus is clear, there is not sufficient evidence to identify them with absolute certainty either with Lower or with Upper Carboniferous forms. Nevertheless, the general facies of the entire assemblage is decidedly 'Upper' in aspect."

Now that strata of Coal-measure age are known to be present at five different localities in the eastern part of Arran, in addition to the one at Sliddery Water Head, an interesting question arises as to the probability of finding workable coal-seams beneath the Newer Red sandstone. It is not likely that such seams occur on the N. end of the island at the Cock, because the unconformability between the two formations is there apparently very slight, and the area where they could possibly be found is so small that it would scarcely be worth while to settle the question by boring. Nor would it be advisable to try the W. side of the island, for as the boundary between the two formations is traced south-westwards from Brodick, the upper series is found to rest successively on lower and lower beds, so that eventually the Carboniferous rocks entirely disappear and the Newer Red rocks and the Old Red Sandstone come into contact. If the matter were to be tested it would be best, therefore, to choose the E. side of the island, and to select a spot several miles away from the Sliddery Water Head area. There is a possible chance of meeting with some of the higher Coal-measures in a district where they have been faulted down previous to the almost conformable deposition of the Newer Red rocks.

Even if the Coal-measures were thus found by boring, however, the coals themselves might be poor, or absent, or destroyed by igneous intrusions so numerous in the island. The "edge" coals which have been worked at the Cock among the Upper limestones are not met with in the corresponding strata at Corrie, though their positions are marked there by the *coal-seats*. Neither has any trace of coal been detected among the rocks exposed at Sliddery Water Head, though in

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the corresponding strata near Kilmarnock coal-seams are abundant; nor has any seam of coal been met with in the other true Coal-measure areas of Arran previously enumerated.

As before remarked, the description of the numerous varieties of intrusive igneous rocks, so abundant in the island in the form of sheets and dykes, does not come within the scope of this paper. No observer in Arran can go far without meeting with them, and as they are abundant in the Newer Red rocks, which are much later than the Coal-measures we have been describing, they must be more recent than both formations. There is every reason to believe that the majority of these intrusions are of Tertiary age and contemporaneous with another great volcanic series, the remains of which are to be found in the N. of Ireland, in the island of Mull, and in Skye. As this series at one time spread over much larger areas than it now occupies, for it has everywhere been extensively denuded, it seems not improbable that true volcanic rocks of this age, which were spread over the surface, existed in Arran at one time, and that many of the intrusive rocks we now see may have been the deep-seated sources of Tertiary lavas. In support of this view we may cite the occurrence of two masses of breccia, very like volcanic necks in structure, which are found at Invercloy on the S. shore of Brodick Bay. As far as can be ascertained they are oval or circular in form, the larger of the two being 150 feet, and the smaller about 50 feet, in diameter. They rise through the Newer Red sandstone and conglomerate, and are composed entirely of fragments of these rocks irregularly arranged and cemented into an agglomerate. It is true there is no igneous material in the masses, but volcanic necks composed entirely of fragments of clastic rocks are not unknown elsewhere.

How wonderfully interesting becomes the geology of this one island, and how much of its ancient history is there yet to discover! The above is but a meagre outline of a small portion of that history, but it shows us that, from at least the earliest Old Red Sandstone times, Arran has many a time been the scene of outpourings from volcanoes, when showers of dust and lapilli were spread over its surfaces, or on the sea-bottom, and streams of lava ran down the sides of its hills—not indeed

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the hills and the surfaces we now see; for all the hill and valley sculpture of the island is probably more recent than the intrusion of the great granite mass in its northern part, the date of which is quite recent compared with that of most of the rocks I have described in the foregoing paper.

Note.—Since the reading of the above paper, a set of volcanic rocks much older than any of those described in it has been discovered in the Island. This series occurs intercalated with the schist of North Glen Sannox, and is probably of Arenig age, and contemporaneous with the trap series of Ballantrae in Ayrshire. A description of these rocks will appear in the forthcoming Report of Progress of the Geological Survey for 1899. (February, 1900.)

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No. XIV.—Notes Retrospective on the Closing of the Quarries of Greenhill, Kilmaurs, Ayrshire. By Robert Craig.

[Read 11th November, 1897.]

Now that the famous Greenhill quarries have been closed, not to be re-opened for a long time, if ever, it seems opportune for me to make a few remarks on their past history, and the reasons why such an interest was taken in them by geologists and palæontologists in bygone years.

The sandstone which has been quarried here for many years is a fine-grained rock, lying near the base of the Kilmarnock coal-field. Though always wrought on the farm of Greenhill, it was better known throughout North Ayrshire as the "Wud'll Sanstane" (Woodhill Sandstone), but the workings became still more widely famed from the fossils found in them, each of the two quarries having its distinctive forms.

The Old Quarry of Greenhill, Kilmaurs.

The older quarry, north of the G. & S.-W. Railway, and higher up the Carmel than the other and newer quarry, became celebrated as far back as 1815, when remains of the Mammoth and the Reindeer were first found in it, as well as Arctic shells, though, so far as is known, there is no existing record of these discoveries.

In the well-known monograph by Mr. (now Sir) Archibald Geikie, "On the Glacial Drift of Scotland," which was published by the Society in 1863,* the first detailed account of the various finds in Greenhill Old Quarry was given, but was hardly satisfactory, from the want of sufficient information. Dr. Scouler had told the author that from 1817 to 1825, in which latter year the last tusk was discovered, nine Mammoth tusks had in all been found, but I believe that at least one other had been found at an earlier date than 1817.

On 4th December, 1829, a tusk was presented to the Hunterian Museum, Glasgow, by Mr. Thomas Fulton, who was proprietor of the lands of Greenhill in the early years of the century, but who sold them to the Earl of Eglinton about 1813 or 1814.

* *Transactions*, vol. i., pt. ii., 1863.

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Now, as no fossil remains of any kind were discovered after the spring of 1825 I am inclined to believe that the tusk in question had been lying for a long time in Mr. Fulton's possession, and was really the first one found, though the last to be made known to the public. It is in the worst state of preservation of all the specimens, probably not having been well looked after while in Mr. Fulton's possession.

But the find which seems to have excited the most general interest was that of a pair of tusks early in 1817. While the overlying bed of clay was being removed to permit of quarrying operations, two Mammoth tusks were found lying together, one well-preserved and fresh, but the other in fragments, too fragile to be handled. The first measured exactly 3 feet 5½ inches in length by 13½ inches in girth, and the other much about the same. Mr. Bald, Engineer, sent an account of the discovery to the Wernerian Society,* having visited the quarry, and also having inspected the portion of one of the tusks preserved in Eglinton Castle, where he at the same time received a good account of the find from Mr. Johnstone, Factor on the Eglinton estate. Dr. Hood, Kilmarnock, Dr. Mackenzie, Irvine, and other observers in the district also sent notes to the Wernerian Society, and to the Ayr newspapers, but none of these are of any particular value, geologically speaking, with the exception of Mr. Johnstone's account.

The only other record of the discovery of a Mammoth tusk in this quarry is that by Professor Jamieson in 1825,† though shortly after this date Dr. Scouler, when visiting the quarry one day, picked up part of a molar tooth, which seems to have been the last fossil found in the Old Quarry of Greenhill.

All the old men who had been about the quarries before and after this period agreed in saying it was before the dry summer of 1826 that the tusks were found, and not after it. Roxburgh, a very intelligent man, who came in 1826, always said that no fossils were discovered after he began work, and that he had heard other workmen say the last find was in 1825.

If, therefore, the information Sir A. Geikie received from Dr. Scouler as to the number of tusks found was correct, several

* *Memoirs of the Wernerian Society*, vol. iv., p. 58.

† *Ib.*, p. 513, and *Edinburgh Philosophical Journal*, vol. iii., p. 182.

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must have been got without any record being preserved of them. Roxburgh, above quoted, did know of one tusk which a workman had found and smuggled home to Kilmaurs, and which was understood to be still in the possession of his family when I first was told of it, now more than 30 years ago.

During all this time the belief was general that the whole of the tusks were found in the true Till, or Boulder-clay, as is stated in the paper "On the Glacial Drift of Scotland," already referred to.* In 1864, a year after its publication, Dr. James Bryce, who like others, had his knowledge widened by the author's views, which revolutionised those generally held by geologists as to the origin of Boulder-clay, came to doubt whether the Mammoth remains obtained at Greenhill really had been found in the Boulder-clay, or in a bed below it, but above the sandstone.

Work had then ceased in the Old Quarry for above 20 years, the surface had been roughly levelled, and a thriving plantation of trees was growing on it. But Dr. Bryce applied to the Duke of Portland through his factor, Mr. Turner, for permission to re-open a section of the quarry, and this request the Duke not only granted, but handsomely offered to pay all expenses incurred in the operations. Dr. Bryce afterwards gave the results of his investigations in a paper read before the Geological Society of London in 1866.†

It is not considered good manners to attack those who have no longer the power of defending themselves, so I shall only say that this inquiry was not well-conducted, by which I do not mean to imply that Dr. Bryce was in any way to blame, but that the factor seems to have directed the work at his own hand, which, as he was not an expert in geology, could not possibly have proved very satisfactory. All these matters, however, I discussed in a paper read before the Society in 1887.‡

Dr. Bryce's paper did not add much to our knowledge of the Mammoth beds, except to give us a section which he had obtained from Roxburgh, the old quarryman, who had been employed

* *Trans.*, vol. i., pt. ii., 1863.

† *Quarterly Journal of the Geological Society*, vol. xxi., 1866, p. 213.

‡ *Trans.*, vol. viii., pt. ii., 1888, p. 213.

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by the factor to re-open the quarry. He afterwards gave a copy of the same section to Mr. Turner, who sent it on to Dr. Bryce.

The first light that broke in upon the darkness enveloping the fossiliferous beds of Greenhill Old Quarry came from the Hunterian Museum, from the hand of the much-respected member of the Society, and my good friend, Dr. John Young, F.G.S. One day when looking over the Mammoth tusks and Reindeer horns in the Museum he lighted upon a small parcel of sand, said to have been taken from the bed in which the horns were found. Seeing that some of the enveloping material still adhered to the tusks, he carefully collected all the sand and clay remaining in the cracks and crevices of the specimens, and washed the gathering with good results, which are fully given in a paper which he read to the Society in 1869.*

In this paper Dr. Young associated my name with his own, as I had supplied him with some notes gathered from coalmasters and others acquainted with Greenhill. There was, however, an error in it, which I was led into by Mr. Yates, jun. He gave me a section of the Greenhill beds, purporting to be taken from the pitsinker's book, but which turned out to be an exact copy of the one given by Dr. Bryce, and did not at all agree with the section of a new pit given in the paper by us.†

When I afterwards met with Thomas Crawford, the sinker of No. 9 Woodhill pit, he told me that this section was wrong, and that the sand-bed with shells really rested on the Carboniferous rock, and was about 5 feet thick, also that a nest of sand had been found in the Boulder-clay as high as 10 feet above the sand. The information given by the sinker that the sand held shells from top to bottom, and that its thickness was 5 feet, was afterwards quite confirmed. When the pit was worked out, and the shaft was being filled up, part of the boarding was removed opposite the sand-bed. Only a few buckets of material were lifted out, when the sand began to run, and the removal had to be stopped. It was, however, seen that the pitsinker was right, that shells were present throughout the sand-bed, and that there was no appearance of any division

* *Trans.*, vol. iii., pt. ii., 1869, p. 310.

† *Ib.*, p. 316.

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of it into separate beds, as had been stated in our paper on Yates's authority.*

When Mr. James Bennie of the Geological Survey was overhauling some old things from the Edinburgh College Museum, he came across a parcel of clay from Greenhill Old Quarry, duly labelled, as he informed me, as that in which a tusk of the Mammoth had been found (half of which tusk had been sent to the Museum and the other half to Eglinton Castle). Following Dr. Young's example he washed this clay, and with equally good results, which he gave in a paper to the Royal Physical Society,† with a general *résumé* of the whole subject.

In the various papers referred to above, and in another by myself on the fossiliferous sand-beds found in pits in the Irvine Valley,‡ in which I was assisted by the late Dr. David Robertson, all the available information on the subject may be found by any one interested in it.

In bringing these few remarks about Greenhill Old Quarry to a close, I have to acknowledge an error of judgment which I committed in the paper of 1869, where I placed the Greenhill Mammoth and Shell bed as an intercalated bed in the Boulder-clay,§ but I have already corrected this in my paper of 1888. I am now convinced that the bed containing the Mammoth and Reindeer remains lies at the base of the glacial deposits, and below the Lower Boulder-clay.

The New Quarry of Greenhill, Kilmaurs.

About 1840 the surface beds covering the rock in Greenhill Old Quarry had risen to nearly 60 feet in thickness, and the workings had been extended close to the road from Crosshouse to Kilmaurs. So the New Quarry was opened further down the Carmel, and south of the old workings. This quarry afterwards became as famed for fossils as the other, though they were of a very different character from those obtained at Old Greenhill. No laminated beds of sand, gravel, or clay, were found beneath the Boulder-clay throughout all the workings of

* *Trans.*, vol. iii., pt. ii., 1869, p. 316.

† *Proceedings of the Royal Physical Society*, vol. viii., 1885, p. 451.

‡ *Trans.*, vol. viii., pt. ii., 1888, p. 226.

§ *Ib.*, vol. iii., pt. ii., 1869, p. 310.

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the New Quarry, and neither mammalian remains nor marine shells were ever got in it, but in a bed of Carboniferous shale from 2 ft. 6 in. to 3 ft. 6 in. thick, resting on the sandstone and overlaid by the Boulder-clay, a number of rather rare crustaceans, and chilognathous myriapods, were found. These fossils were first brought to the notice of geologists by Thomas Brown, a hand-loom weaver in Stewarton. A shopmate of his, called Miller, described Brown to me as a bright intelligent man in his youth, but that "after he took to 'wandering' and fossil-hunting, he was like a man no verra richt in the head." I have myself seen and spoken to Brown, and he appeared to me rather to try to avoid meeting people whom he did not know —a timid kind of man. When he opened out somewhat in conversation, I found that he did not know much of geology generally, but that for years he had been a diligent worker during the long summer days at the bed of whitish clay-shale exposed in Greenhill New Quarry, where the crustacean remains were found in nodules of impure ironstone. Roxburgh, the lessee of the quarry, who lived close by, told me that Brown's general practice was to arrive just after the workmen had left for the day, and that he would split away at the nodules as long as he could see. He had often seen him leaving for Stewarton, more than 4 miles distant, at half-past 10 p.m., carrying a home-woven napkin filled with chips of the nodules.

Brown was a more successful finder of the fossils here than any other person who ever tried to gather them, and it lately struck me when looking over the beds one day that he may have known something more than any of the other collectors, as, for instance, that the crustaceans did not extend over all the bed, but were confined to one or more bands in it. Such fossil-bearing bands are frequent in shales, and a collector who has noted something of the kind has naturally a great advantage over others who are not so well-informed.

Latterly Beveridge, a pit contractor, Linton of Kilmaurs, Macallister, son of the Greenhill farmer, and others, worked at collecting the fossils, and practically did not leave a nodule unbroken. The fragments looked like road metal on a newly repaired road, and yet the results from them were as nothing compared to those from the comparatively smaller number of

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nodules broken in Brown's time. It was this fact that made me think of a possibly restricted area, but I never have had the chance of proving it.

The only published paper referring to the New Quarry and its interesting crustacean remains, with which I am acquainted, is one on Carboniferous Articulata by Dr. Henry Woodward, which was published by the Society in 1867.* Mr. Farie, then Hon. Secretary, had heard something of Thomas Brown and his collection of crustacea from Greenhill, and, getting possession of at least a portion of it, he sent specimens to Dr. Woodward, whose remarks in the paper quoted do not give any account of Brown's work, nor any reference to the local position of the fossils, further than that they were found at Kilmaurs in the Ayrshire Coal-field. The paper is really more palæontological than descriptive, so that, instead of entering into local details which would interest us now, it merely draws a comparison between the forms themselves and similar ones found in other parts of the world—such as Nova Scotia, Germany, and Colebrookdale in England. So far as I know, it is probable that a number of the fossils found in Greenhill New Quarry are still undescribed—Dr. Woodward named only four of them—*Pygocephalus Cooperi*, Huxley; *Prestwichia rotundata*, Woodward; *Belinurus trilobitoides*, König; and *Xylobius sigillariæ*, Dawson, besides a portion of a King Crab not described.

Brown's collection went into the possession of a nephew, who was a gardener at Ardrossan, about 20 years ago, but I have lost sight of him since that time. He was under the impression that a number of the specimens originally in the collection had been lost, and he had suspicions that they had been lent by his uncle to some one who never returned them.

This exhausts any remarks that I am able to make about the Greenhill Quarries, Old and New, of Kilmaurs, Ayrshire.

* *Trans.*, vol. ii., pt. iii., 1867, p. 234.

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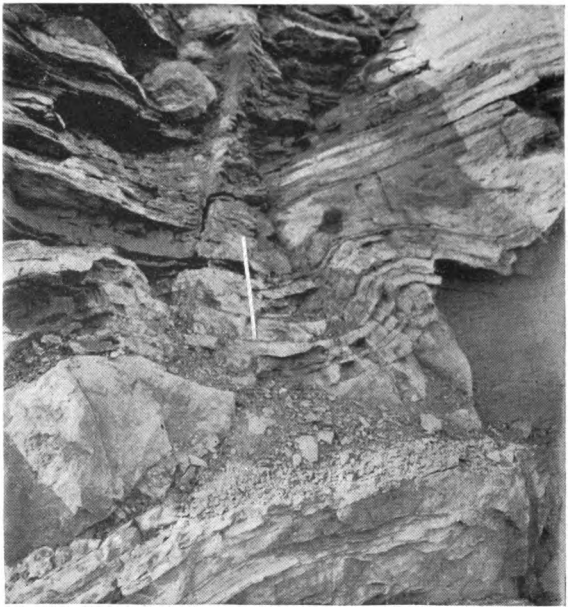
I.—General View of Syncline, New Braidbar Quarry.



II.—Centre of Syncline showing maximum contortions, New Braidbar Quarry.

From Photos by S. Fingland. *Hislop & Day, Photo Engs.*

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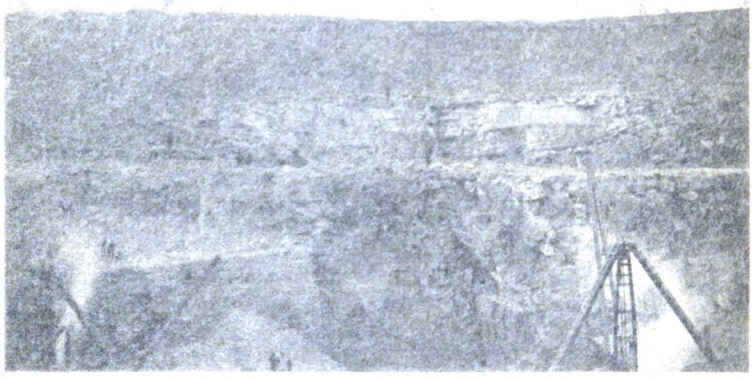
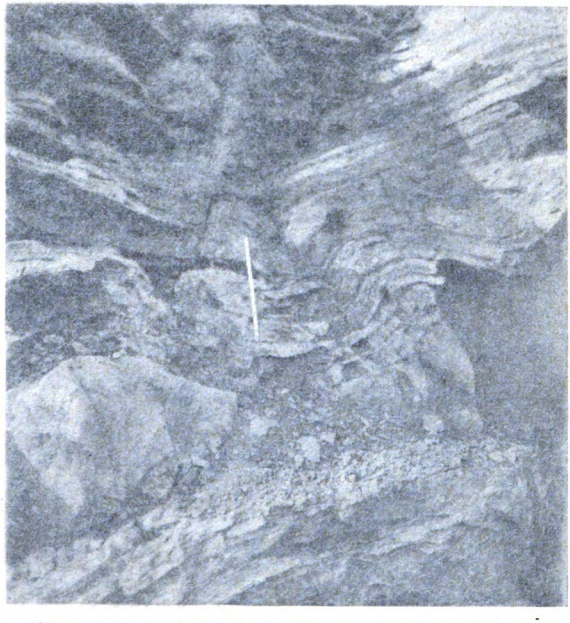


I. - General View of Syncline, New Braidbar Quarry.



II. - Centre of Syncline showing maximum contortions, New Braidbar Quarry.

From Photo. by S. England. Hislop & Day, Photo Engs.

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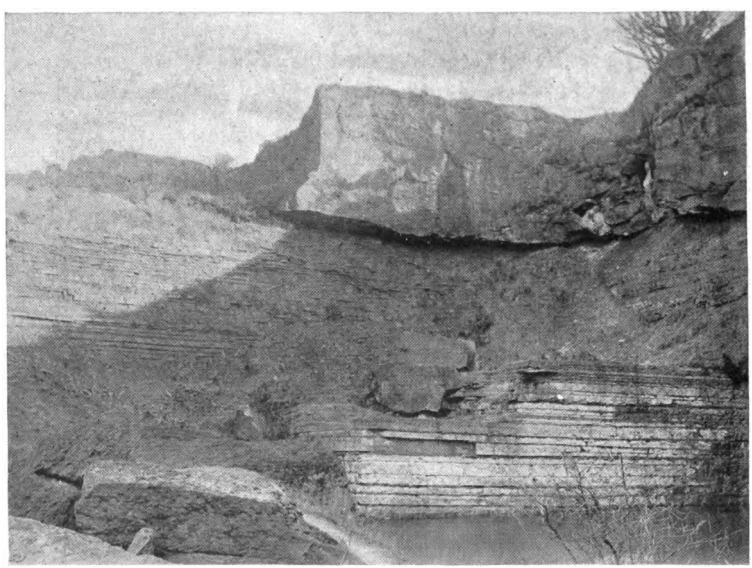
I.—Right Limb of Syncline showing contortions and erect tree stem, New Braidbar Quarry.



II.—Flagstones with Annelid Tubes and local unconformity, Burnfield Quarry.

From Photos by S. Fingland. *Hislop & Day, Photo Engs.*

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No. XV.—On the Physical Geology and Palæontology of the Giffnock Sandstones, and their Bearings on the Origin of Sandstone Rock generally. By Peter Macnair. With Two Plates [Nos. IX. and X.] and Eleven Diagrams.

[Read 9th December, 1897; 10th April, 1898; and 9th March, 1899.]

I. Introduction.

The well-known Giffnock Sandstone quarries are situated near the station of that name on the East Kilbride Railway, and east and west of the New Kilmarnock Road, about 4 miles from the Exchange, Glasgow.

To many local geologists they are associated with early ideas of the "stony science" as, being easily accessible from the city, they are often visited by excursionists from the various science classes and others. It seems singular, however, that no detailed account of their many interesting features has yet been given in our *Transactions*, nor any serious attempt made to solve the numerous and obscure problems which their strata present. It has been too freely assumed that their phenomena are of the simplest character, and that they offer few or no difficulties to the geological observer. But as I take a very different view, I propose, in the following paper, after giving a description of the various notable exposures to be found in them, to point out wherein our knowledge of these rocks has neither been so definite nor so full as might be supposed, and that there is still room for considerable latitude of opinion regarding their formation.

The principal workings in the Giffnock sandstones lie to the east of the New Kilmarnock Road, and consist of three separate quarries, known respectively as Braidbar, New Braidbar, and Williamwood. Braidbar lies nearest the road and the railway, while New Braidbar, the only one at present worked, lies on the other side of a knoll of rising ground, beneath which runs a large series of tunnels connecting the two quarries. The tunnels, or galleries as they might be called, are about 16 feet wide, and in some cases, as much as 40 to 50 feet high, and transverse passages diverge at intervals from the main roadways, to which they are cut at right angles. These underground

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workings present to the explorer quite an imposing appearance in the dim working light, and even suggest the vaulted aspect of some ancient Saxon cathedral. They have all been excavated along the line of a particular bed of rock, the principal source of the best building-stone. Williamwood, which lies further to the south-east than the others, has not been worked for a considerable period. The principal features of interest are its beds of flaggy sandstone and shale, these not being met with in either of the Braidbar quarries.

For working purposes the Giffnock quarrymen recognise two kinds of sandstone, which they name respectively the "liver rock" and the "moor rock." As to the origin of these terms, it has been said that the former is so called because of the ease with which it can be cut in any direction, being quite devoid of stratification; while the "moor rock" most likely derives its name from the same source as the moor rock or millstone grit because it marks the limit of the more valuable building rock in the same way as the millstone grit marks the lower limit of the true Coal-beds. The tunnels already mentioned have been excavated along the bed of the "liver rock," of which, of course, their walls and pillars are also formed, while the overlying "moor rock" composes their roofs. This may be well seen in the Braidbar and Williamwood quarries, where the "moor rock" forms, so to speak, the lintels, and the "liver rock" the doorposts, of the underground entrances.

West of the Kilmarnock Road another group of sandstone quarries stretches nearly to Thornliebank Station. None of these have recently been worked, nor have they at any time been so extensive as the first-mentioned workings, but they contain some interesting geological features which are not present elsewhere in the district. To distinguish them I propose to call them the "Burnfield" quarries after the farm they are on, though originally that was the name of their north-western part only.

The sandstones of the Bishopbriggs quarries, north of Glasgow, are on the same horizon as those of Giffnock, and present much the same features. Certain phenomena are also common to both localities, and by studying them together we shall gain a better idea of the conditions under which the rocks

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were deposited. A very fine section of the Bishopbriggs sandstones, shales, and limestones, which may be seen along the line of the North British Railway to Edinburgh, was described and figured many years ago in the Society's *Transactions* by Prof. Young and Mr. [afterwards Dr.] John Young.* I propose to take up some points relating to this section later on.

As the main object of the present paper is to examine the evidences bearing upon the physical conditions under which the Giffnock sandstones were laid down, we shall have to consider their various petrological, stratigraphical, and palæontological characters, and note the bearings of the combined testimony. Great differences of opinion exist as to their deposition, some observers maintaining that they are of marine origin, and others that they are of freshwater formation, while a third party believe that they are brackish-water or estuarine beds. These various views will, perhaps, not surprise us, when the nature of the evidence comes to be examined.

It will be interesting to see what light the study of these sandstones throws upon the wider and more important question of the deposition of the Scottish palæozoic sandstones generally, but as there will not be space to discuss the evidence fully, I shall confine myself to pointing out the weaknesses of many of the arguments brought forward in support of the freshwater theory of their origin, and then show that these arguments are really strongly in favour of the theory of marine deposition.

II.—Opinions regarding the Origin of the Scottish Palæozoic Sandstones generally.

From the almost entire absence of organic remains in the great masses of barren sandstones found in the palæozoic rocks of Scotland, of which the arenaceous rocks form by far the greatest bulk, it has been inferred by such eminent geologists as Godwin Austin, Ramsay, and Geikie, that they are of freshwater origin, a conclusion that is almost wholly based upon negative evidence. The uncertainty as to the exact conditions under which many of the later palæozoic sandstones were laid down was well shown in Mr. Goodchild's recent lecture to the Society on "Desert Conditions in Britain," in which he presented

* *Trans.*, vol. ii., pt. iii., 1867, p. 283.

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the novel and somewhat startling view that amongst these rocks in Scotland there occur beds which were not deposited in water at all, but are entirely due to the weathering of land-surfaces by sub-aerial agents, and having their modern counterparts in the present "desert conditions" of the north of Africa.*

Two theories have been advanced, more or less tentatively, to account for the phenomena presented by the Scottish Carboniferous rocks, the one that they were deposited on the low sloping shores of an open sea, the other that they were laid down in land-locked basins. According to the first theory, the one most generally adopted, these rocks were thrown down along the margin of a sinking land-surface, which, shelving outwards from the main mass, passed into the open sea, but at no time could have been so land-locked as to possibly become a freshwater basin. Such brackish-water beds as are found in the Coal-measures are supposed to have been formed as estuarine deposits along the margins of these gradually-shelving shore-lines, upon which rivers emptied a plentiful supply of mud and sand, while along the coast-line there were great areas of brackish water. We are not without evidence that characteristic marine species at times invaded them, as the occurrence of marine shells in the Upper Coal-measures—*Productus scabriculus*, *Discina nitida*, *Conularia quadrisulcata*, *Bellerophon Urii*, and *Axinus deltoideus*—was recorded in the *Transactions* in 1865 by Mr. R. Whyte Skipsey,† while specimens of *Aviculopecten*, *Orthoceratites*, and other marine forms, from the Upper Coal-measures of Airdrie, were exhibited by Mr. Robert Dunlop at a meeting of the Society in 1886.‡ From such evidence it is permissible to suppose that by diligent search many more examples of similar forms might be brought to our knowledge, which would still further strengthen my contention that the Upper Coal-measures are essentially a marine formation.

The other theory, that the Carboniferous rocks were laid down in a land-locked basin, filled at certain periods with fresh, and at other times with salt, water, is attended with

* *Trans.*, vol. xi., pt. i., 1898, p. 71.
† *Ib.*, vol. ii., pt. i., 1865, p. 52.
‡ *Ib.*, vol. viii., pt. ii., 1888, p. 342.

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many difficulties, but these I cannot now enter upon. Mr. James Neilson lately did battle for it, and in referring to the conditions under which the Upper Coal-measures were laid down, he remarked—"The evidence is entirely of land or fresh-"water conditions, and there is, unless in very exceptional "cases, no more evidence of marine conditions, than there "would be even if the sea had ceased to exist. As we can "hardly imagine the existence of a true estuarine bed from "which marine organisms were entirely absent, we submit that "it would be well to cease naming such beds 'estuarine,' and "simply to call them freshwater beds." * Again he says—"The word 'estuarine' has been applied very loosely to beds "which their fossil contents show to have been laid down in "fresh water, and the term has consequently been applied to "the whole of the Upper Coal-measures, the Middle Ironstone "and Coal series, and the Calciferous series" (which Mr. Neilson considers to be of fresh water origin). †

In his Presidential Address to the Royal Physical Society of Edinburgh for 1881, Mr. R. Etheridge, jun., in referring to the physical conditions under which the Coal-measures were accumulated, says—"Much writing has been written, and many papers published to prove the marine deposition of the Coal-measures in general, but I take it that the special occurrence of marine bands in the measures proves only, and specially, the occasional occurrence of truly marine conditions. We must look upon the sediments in which the genera *Anthracosia*, *Anthracoptera*, and *Anthracomya* occur as either of a brackish, or fresh water origin. The probability appears to be, speaking purely from personal experience in a climate where creek and brackish vegetation attains a luxuriant growth, accompanied by a rapid humus-accumulation of soil, that the brackish water theory deserves more attention than any other which has been advanced." ‡

Without entering into the details of these rival theories, and of the palæontological arguments for and against the estuarine and freshwater ones respectively, it may be pointed

* *Trans.*, vol. x., pt. i., 1895, p. 69.

† *Ib.*, p. 66.

‡ *Proceedings of the Royal Physical Society*, vol. vii., 1882, p. 90.

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out that the existence among these Carboniferous groups of massive beds of sandstone entirely devoid of fossil remains, except, perhaps, a few casts of land-plants, and common both in the Calciferous Sandstone series, the Lower and Upper Limestone series, and the Coal-measures, the paucity of organic remains is generally considered to be indicative of original freshwater conditions of deposit.

In the Calciferous Sandstones of the West of Scotland there is a group of greyish-white sandstones with beds of impure dolomitic limestone, the only contained fossils being a few plant-remains and some fish-scales. From this positive evidence, combined with the weightier negative evidence that they are otherwise absolutely barren of organic remains, it has been concluded that the group is of freshwater origin.

Though some doubt exists as to the exact conditions under which the great courses of barren sandstones interbedded in the Scottish Carboniferous Limestone series were deposited, I should hardly have supposed that even the most strenuous upholder of the basin theory would look upon the Giffnock sandstones as of freshwater origin, yet I have lately met several of our members, who, having devoted considerable attention to these rocks, believe that they have been formed under such conditions.

In a note appended to a paper by Messrs. John Young and James Armstrong, on "The Fossils of the Carboniferous Strata of the West of Scotland," published in 1873, in which they refer to a section of the Lower Limestone series in a pit at Campsie, consisting of a group of sandstones and shales with one or two beds of marine limestone, the authors make the following remarks regarding the conditions under which the rocks were accumulated—"Except in the limestone bands fossils are very rare throughout the other members of the group; those that have been met with are generally fragmentary remains of plants and fishes scattered through the sandstones and shales. These are of types that indicate land, fresh, and brackish-water conditions, the widely separated limestones with their overlying shales being the only strata which from their fossils present us with periods when true marine conditions prevailed." *

* *Trans.*, vol. iv., pt. iii., 1874, p. 267.

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In the Upper Coal-measures, as in the Limestone series, a large percentage of the beds consist of barren sandstones which may, or may not, be of freshwater origin, but the determination of the point must be more or less dependent on the nature of the fossiliferous beds amongst which they occur. The balance of evidence is I think in favour of the view that the Upper Coal-measures are of marine origin, so far as it opposes the view that these beds were deposited in a land-locked basin of fresh water, and favours the idea that they were formed along the margin of a slowly-sinking shore-line, where estuarine or delta conditions prevailed for many miles along the low flat shelving shores which passed outwards into the open sea.

The most striking group of barren sandstones in the later palæozoic rocks of Scotland is that which constitutes the well-known Old Red Sandstone formation. Over many square miles, both in the centre and in the north of Scotland, those sandstones occur, in some cases of enormous thickness, and absolutely devoid of any traces of life, except in certain limited horizons the remains of land-plants, and of fishes and crustaceans. Of late years it has been freely assumed that the evidence is entirely in favour of the view that those sandstones have been accumulated under freshwater conditions, the presence of land-plants, the occurrence of fishes whose modern representatives inhabit lakes and rivers, and the absence of undoubted marine forms, being some of the arguments advanced. But land-plants occur in rocks of undoubted marine origin as frequently as they do in the Old Red Sandstone beds, and the value of the evidence derived from the occurrence at the present day of ganoids in freshwater lakes and in rivers is more than counterbalanced by the proof that in palæozoic times these fishes were undoubtedly marine, or to use the significant words of Rütimeyer that a "flight into fresh water has been their salvation."

The unique group of rocks found along the north-west coast of Scotland, known as the Torridon Sandstones, at one time covered a much larger area and reached a much greater thickness than their isolated tracts and mountains now show. The singular point regarding them which has struck most observers is that no trace of organic remains has ever been met with in

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any of their numerous natural sections exposed along the coast, and amongst the mountains of the north-west of Ross and Sutherland, a fact rendered still more remarkable from the apparently unaltered condition of the rocks themselves.

Such, then, is a brief recapitulation of the leading features of the great masses of barren sandstones found in the Scottish palæozoic rocks, and of the opinions of observers regarding them, my object being to show that the absence of organic remains from the arenaceous rocks cannot be taken in itself as evidence of their freshwater origin.

In the course of the following pages I hope to prove that in the Giffnock sandstones we have a group of rocks which must have been laid down under ordinary marine conditions, though they are now almost entirely non-fossiliferous with the exception of a few plant-remains.

III.—Lithology of the Giffnock Sandstones.

The lithological features of the different strata exposed in the Giffnock quarries are of the most interesting character. Thus the "liver rock" in the Braidbar workings, and a bed of sandstone, probably on the same horizon, in the Burnfield quarries, show scarcely any stratification, the sand-grains having evidently been deposited in deep water below the arranging influence of the tides.

Large nodular masses of hard sandstone which occur in the "liver rock," some parts being literally crowded with them, are known to the quarrymen as "whinny boles." They weather with a rusty brown colour owing to the presence of carbonate of iron. In a paper by Mr. J. Wallace Young, in the *Transactions* for 1867,* their analysis was given:—

	Ordinary Sandstone.	"Whinny Boles."
Carbonate of Lime,	4·78	19·53
Carbonate of Magnesia,	2·49	10·62
Carbonate of Iron,	2·36	9·65
Total Carbonates,	9·63	39·80

This shows a considerable percentage of carbonates in the "whinny boles," the lime being sufficient to effervesce with acid. In the same paper Mr. Wallace Young quotes from Prof.

* *Trans.*, vol. ii., pt. ii., 1867, p. 204.

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Church:—"At Bude Haven, Cornwall, and elsewhere, coarse grained sand is in many places being cemented together by the action of the water of land springs containing carbonic acid, which, percolating through the sand and dissolving the fragments of shells contained therein, the carbonate of lime is subsequently at some other point slowly deposited as the carbonic acid escapes, thus forming a cementing material for the sand." This seems a very probable explanation of the origin of these curious nodules in the "liver rock."

The greatest variety of structure is found in the "moor rock." Irregular bands of grit occur in it at certain points, the quartz pebbles sometimes exceeding ½ an inch in diameter. These grits are well seen in an old working at Hillfield about a mile south of Thornliebank, where they are exposed just above a strong line of local unconformity or erosion. It also frequently contains beds of flaggy sandstone with very thin partings of shale, and, unlike the "liver rock," usually shows well-marked lines of stratification. Near the east end of New Braidbar quarry, where the sandstones are very fine-grained, the "moor rock" presents a beautifully banded appearance, and shows evidence of having been laid down under shallow-water conditions, as it contains ripple-marks over extensive areas, as well as of current-bedding. Some fine examples of these occur at New Braidbar, but perhaps the most striking specimen of current-bedded rock is that underlying the flagstones in Burnfield quarries.

The Giffnock sandstones, having been originally laid down as ordinary sea-shore deposits, must have been highly charged with the remains of marine organisms, which were afterwards entirely removed by some such process as the one mentioned by Prof. Church, and probably long before the sand itself had become consolidated.

The limestones interbedded with these sandstones, and from which this group of rocks derive their names, such as the "Cowglen," the "Orchard," and the "Arden" limestones, have a compact, fine-grained texture, and contain an admixture of silica and alumina, which renders them particularly suitable for cement, hence they have been generally known as "cement-limestones." They contain few fossils, but the adjacent shale

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beds, which seem to be well suited for the preservation of organic remains, are crowded.

IV.—Stratigraphy of the Giffnock Sandstones.

These sandstones belong to the Upper Limestone series of the Scottish Carboniferous formation. Immediately south of the Giffnock Railway Station a bed long wrought for cement was locally known as the "Orchard limestone" from the name of the farm on which it was placed. Below it occurs a bed of shale, which yielded to collectors an immense profusion of marine organisms, being, in fact, one of the richest localities in the West of Scotland for Carboniferous fossils. As the dip of the sandstones is south and east they doubtless underlie this limestone and shale, though these beds have not yet been reached in the quarries. Probably they will be exposed when the workings there are continued southwards, and a fresh opportunity will then be afforded for collecting the fine series of fossils yielded by the shale.

Still further south the Orchard limestone is overlaid by a group of sandstones and shales, which pass upwards into the Arden limestone, long worked near Thornliebank, and more recently nearer Barrhead. This bed, which has in some places a thickness of over 10 feet, marks the top of the Limestone series in this locality.

Below the Giffnock sandstones to the north, occur two beds known respectively as the Holeburn limestone, and the Cowglen, or "Index" limestone, the existence of the former being first demonstrated by Captain James Stewart of Williamwood, in a paper which he submitted to the Society in 1881.* The Holeburn limestone and the overlying sandstones are repeated by the action of a fault which passes to the south of Merrilea Wood.

Such is a brief recapitulation of the series to which the Giffnock sandstones belong, and we may keep in view its character as of great value in helping us to form a conclusion regarding the principal conditions of the deposition of these rocks.

* "Notes on the Limestones in the Parishes of Cathcart and Eastwood, Renfrewshire. By James Stewart of Williamwood, with Map and Section." *Trans.*, vol. vii., pt. i., 1883, p. 158.

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On entering Burnfield quarries from the Thornliebank Road near the farmhouse, we find a series of old workings lying roughly along the strike of the rocks, and parallel with the East Kilbride railway, the general dip of the strata being south at a low angle averaging 5 degrees. The lowest beds are thus exposed in the most northerly part, and higher strata are reached as we proceed southwards. The lowest group seen just east of the station consists of irregularly-bedded sandstones, the result of current-action, which pass downwards into a more massive and finer series of white sandstones well exposed still further to the east. These latter are clearly on the same horizon as the "liver rock" of Braidbar and

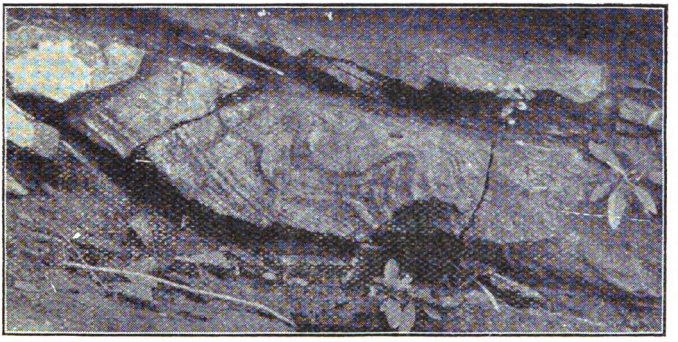

Fig. 1.—Contorted Sandstones, Burnfield, from a Photograph by W. Jeffrey.

Williamwood, while the false-bedded sandstones which succeed them may be the equivalents of the "moor rock." It was in these current-bedded sandstones that I first saw evidences of the peculiar contortions and flexures to which certain zones of the Giffnock sandstones have been subjected, and fine examples may be seen on the sides of a road leading to the Burnfield flagstone quarries (fig. 1). Though their general dip is at such a low angle as to appear almost horizontal, yet in one place a bed of flaggy sandstone has been bent into a nearly perpendicular position, and in another the false-bedded sandstones have been thrown into a series of folds, of which the longer axes vary from 9 up to 20 inches in diameter.*

* The axes of the folds generally head N.W., which shows that the push has been from that direction.

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The current-bedded sandstones pass upwards into the well-known flagstone series with its annelid burrows, consisting of sandstones with thin alternating layers of sandy shale, the former varying from 1 foot thick to a mere streak. In the whole exposure I counted not less than 50 alternations of sandstone and shale. The general dip is south about 5 degrees. Where best exposed the total thickness of the series is about 20 feet, though the passage into the underlying beds is not seen at this point.

Fig. 2.—Section, Burnfield.

Fig. 2 gives a diagrammatic section across the Burnfield quarries, showing the relationships of the false-bedded sandstones, A, to the flagstones above, B, which are overlaid by an upper sandstone, C, highly charged with the decorticated remains of *Lepidodendron*, *Stigmaria*, &c.

Towards the west the flagstones cannot be traced beyond the quarries, as there are no exposures in that direction. About 100 yards east, however, they dwindle rapidly, first to a few feet and then to less than 1 foot in thickness, but the distinct unconformity is retained, and an upper series of sandstones, resting on the denuded surface of the flagstones lie on the lower group of false-bedded sandstones without any intervening strata. Their final disappearance may be seen in the cutting directly underneath the farmhouse.

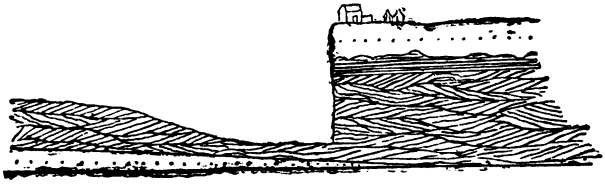

Fig. 3.—Section, Burnfield.

Fig. 3 shows the almost final disappearance of the annelid flagstones, there being only a few beds between the massive sandstones above, and the false-bedded ones below.

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Whether this rapid dwindling is the result of the denudation to which these rocks have been subjected, or whether it is owing to the passage of the annelid flagstones into the false-bedded sandstones, I have not been able to determine. At the point where they die out the characteristic current-bedded sandstones below, and the group with tree-stems above, seem to meet, and it is probable, therefore, that the intermediate series of flagstones have here been entirely denuded away, involving a removal of over 20 feet of strata.

The base of the overlying sandstones, where it rests in the hollows of the flagstones, is marked by a strong bed of grit, drifted into them, and which is seen to transgress their beds at as high an angle as 25 degrees. The line of junction marking the unconformity between the two beds is generally occupied by a line of shaley, or carbonaceous, material. About 200 yards south of the flagstone quarry there are traces of another unconformity, evidently on a higher horizon. Such cases of local unconformity are not uncommon all through the Giffnock sandstones, and there are some very interesting examples in Hillfield quarry, south of Thornliebank.

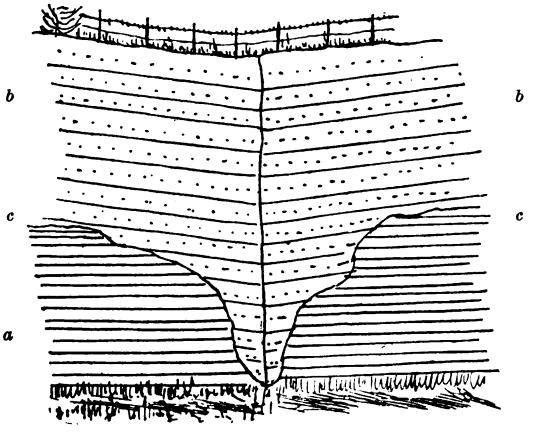

Fig. 4.—Line of Unconformity and Local Erosion, Burnfield.

Fig. 4 gives a striking example of the irregular base on which the upper sandstones rest, a little south of the Burnfield

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flagstone quarry. The flagstones are marked *aa*, the upper sandstones *bb*, and the line of unconformity *cc*.

At one time I thought that this well-marked unconformity above the flagstones might be in some way connected with the evidence of movement in the rocks beneath. I shall, in the following section, discuss the point in more detail.

Passing now to New Braidbar, it will be evident, from the position of the tunnels, that the lowest rock exposed is the well-known "liver rock," which dips south-west at a low angle. Immediately above it, and forming the roof of the tunnels, we have the "moor rock," best seen in the face at New Braidbar and Williamwood quarries. Like the "liver rock" it is formed of massive beds of sandstone with little stratification, but, unlike it, is intersected by numerous lines of unconformity or local erosion, with subsequent unequal deposition. These divide the sandstones into irregular masses, and strongly remind one of the line of unconformity between the annelid flags and shales of the Burnfield quarry and their overlying sandstones. Such local unconformities represent periods when the sandstones were upheaved and formed land-surfaces where trees and other plants grew, as is borne out by the existence of thin partings of coal and earthy-like shale, bearing a striking resemblance to the surface-washings of present-day land-surfaces. In the course of time these were again submerged, and the irregular surfaces covered by the deposition of the more or less massive beds of sandstone, the process of submergence and upheaval of the sea-floor having, seemingly, been repeated over and over again.

Above the "moor rock," as seen along the top of New Braidbar quarry, there is a group of thin flaggy sandstones with beds of shale, which is also exposed further east in the Williamwood workings, but is there separated from the "moor rock" by a line of local unconformity so strongly marked as to indicate a continued period of erosion. As the surface of the "moor rock" is exceedingly irregular the base of the flagstone and shale group undulates round all its knobs and fills up all its hollows. The finest section of these rocks is exposed in Williamwood, where they reach a considerable thickness.

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In New Braidbar quarry only some of the lower beds are visible, but they are interesting, having been bent in a peculiar manner near the south-east end into a synclinal trough. The rocks in this syncline consist of a series of flaggy sandstones and shales with ironstone nodules, and thin partings of coal and fireclay, in the following descending order:—

	Feet.	Inches.
1. Shale, - - - -	1	0
2. Flaggy Sandstone, - - -	7	7
3. Shale, - - - -	0	9
4. Flaggy Sandstone, - - -	5	9
5. Shale, - - - -	1	0
6. Sandstone, - - - -	1	2
7. Shale and Sandstone, - -	6	9
8. Coal, - - - -	1	2
9. "Moor Rock," - - -		

In this section, No. 8, a coal, rests immediately on the "moor rock," but is separated from it by a line of unconformity. No. 7 is a thick shale-bed with occasional sandstone partings in which occur trunks of trees standing in an upright position. No. 6 is a sandstone, and No. 5, a thin shale-bed. A flaggy sandstone, No. 4, is the bed which shows such extreme contortions towards the centre of the syncline, and No. 3, above it, is another shale-bed, so that the contorted strata in No. 4 are both overlaid and underlaid by shale. No. 2, a flaggy sandstone, passes upwards into No. 1, a shale, the highest member of the syncline.

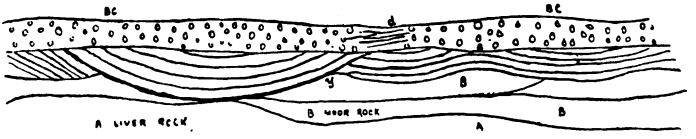

Fig. 5.—Diagrammatic Section showing Syncline of Strata, New Braidbar.

The diagrammatic section (fig. 5) will make this more clear. Lowest of all is the "liver rock," A, and above it, separated by a line of local unconformity is the "moor rock," B, intersected by numerous lines indicating false-bedding. Above, and separated from it by a long period of erosion (shown by

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the heavy line in the section), is C, the shale and flaggy sandstone series.

The highest strata in this section are exposed where they crop out from beneath a mass of Boulder-clay. They evidently occupy a higher position in the syncline than any of those given in the foregoing table, but seem to be of much the same character as those near its base, principally flaggy sandstones, and shales full of ironstone nodules with *Lingula mytiloides* and *Discina nitida*, these fossils also occurring in the shale itself.

If the general dip of the rocks here be taken as S.W., the section has exposed the syncline, roughly speaking, along the strike of the strata, which all dip towards a centre, or have what is known as a centroclinal dip. Thus the centre of this trough, so far as now exposed, dips S.W. like the beds further east in Williamwood quarry. Its left limb is W.N.W., and its right S.S.E., from which it is evident that the quarrymen have not yet reached the centre of the basin, for in that case the respective dips of the right and left limbs would be N.W. and S.E. I therefore conclude that the folding of the rocks is of an entirely local character, or, in other words, that their dips are of a qua-qua-versal order, and that we have here a basin-shaped hollow whose width from lip to lip may be taken as represented by the width of the section now exposed.

The local nature of the folds is also clearly brought out by a consideration of the position and relationships of the flaggy sandstones and shales in Williamwood, where they are seen to rest on the "moor rock" without any evidence of disturbance, and dip S.W. In it there seems to be, however, a considerable pitch of the beds along the strike, rising from, or dipping to, the syncline exposed in New Braidbar quarry, so that the syncline probably represents the point where the maximum amount of disturbance has taken place in a wider though much shallower basin of depression, which included the "liver rock," "moor rock," and flaggy sandstones. This view seems to be borne out by the fact that the syncline showing the extreme contortions of the strata is confined to one particular group, and this only of a very limited nature.

Fig. 6 is an enlarged diagrammatic section of the syncline,

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which shows that the contortions are confined to the flaggy sandstone, No. 4 of the section, and that where it passes into the centre of the syncline it has become highly contorted

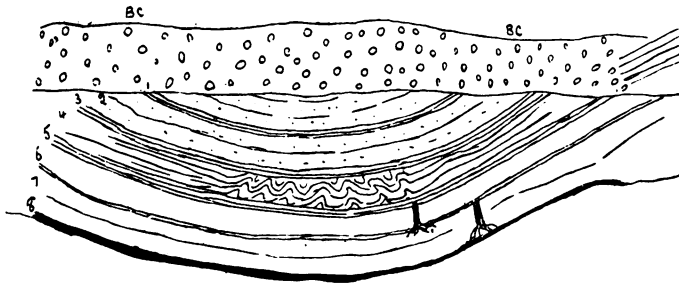

Fig. 6.—Enlarged Diagram of the Syncline, New Braidbar.

and folded, indicating that the maximum amount of pressure has there taken place. For about 15 feet these flagstones seem to have slipped, and to have been contorted between the underlying and overlying beds of shale.

V.—Origin and Age of the Movements in the Giffnock Sandstones.

From the evidence bearing on the movements in the Giffnock sandstones it was originally supposed that they may have been caused by the proximity of lines of fault, resulting in the contortion of the strata. The Burnfield section, however, shows no indications of faults, as the false-bedded sandstones which contain the crumplings dip regularly below the flagstones. Besides, the contortions are exposed all along the section, which would hardly have been the case if they were the result of faulting. Nor is any near fault shown in the Survey maps of the district.

The contorted flagstones at New Braidbar do not support such a theory, nor do the underlying "moor rock" and "liver rock," which are exposed where a trench has been cut into them. Again, the position and extent of the crushed beds in the syncline entirely preclude the possibility of their having been the result of normal faulting. It is evident that if the crumplings had been caused by nearness to a line of fault they would have

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been distributed along a corresponding line, whereas they lie along a zone of flaggy sandstones and parallel with its bedding.

Certain phenomena at Coltpark, Bishopbriggs, which bear a striking resemblance to those at Giffnock, were noticed in the *Transactions*, as already stated, by Prof. Young and Dr. John Young—a group of flagstones standing almost vertically, and overlaid by more massive and nearly horizontal beds of sandstone.* They argue that extensive denudation has taken place between the upheaval of the flagstones and the deposition of the sandstones, as indicated by the irregular line of junction. A thin layer of vegetable matter, converted into coal in places, intervenes between the beds, and follows the superficial irregularities of the lower one. These authors also suggest that the vertical sandstones may have been acted on by a neighbouring dyke, which would have elevated the strata so as to form a small island in the Carboniferous sea.

There is, however, no evidence of any dyke near the disturbed strata, but even if one was present, and had an upheaving power, it would rather have formed a long ridge than an island. Another objection, and a fatal one, to the theory, is that any dykes in the district are now known to be much younger than Carboniferous times, and so not in existence at the date of the movements in the rocks. If the upheaval of the Bishopbriggs beds was contemporaneous with those at Giffnock, and consequently a larger area was involved than was formerly supposed, it points to a more general agency than a mere dyke as the cause of the disturbances.

In the paper above quoted certain beds in the Bishopbriggs section which appear to transgress unconformably a lower set are alluded to, and this action the authors refer to denudation consequent upon slight shiftings of level.

The lines of local erosion at Giffnock already described, which separate the "moor rock" from the overlying flagstones and shales (see fig. 5) have been compared to lines of thrust, the "moor rock" having been pushed between the "liver rock" and the sandstones and shales, with the result that the latter have not only been bent into a basin, but have been curved and contorted as we now see them. (See figs. 5 and 6, and Plate I., photo-

* *Trans.*, vol. ii., pt. iii., 1867, p. 283.

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graphs 1 and 2.) In support of this view it has been pointed out that a "nose of thrust" so-called, of the "moor rock" has been pushed in to the left of the western limb of the syncline, and probably has been partly its cause. Its position is shown at *y* in fig. 5.

There is, I think, no evidence in favour of these theories, but a good deal against them.

First, that the "moor rock" has been thrust between the "liver rock" and the flaggy sandstones cannot, I think, be maintained for a moment, as the whole stratigraphical evidence goes to prove that these strata occupy their normal position. An inspection of the rocks or a study of the 6-inch Survey map will show that in all the exposures and borings, from the Arden down to the Cowglen limestone, there is a steady dip S.S.E., and S.W., and that all the beds apparently lie conformably on one another.

Second, that this "nose" has been the direct agent which has pushed up the western limb of the syncline, acting, in fact, like an intrusive rock, is quite out of the question, because the "nose" is merely the dying-out of one of the irregular massive beds of "moor rock" along a line of contemporaneous erosion, as already described; or in other words, it is just the irregular surface of the "moor rock," on which the flagstones and shales were subsequently laid down.

Third, that all the surfaces along the alleged lines of thrust are slickensided is equally doubtful. What has been frequently pointed out to me as slickensided surfaces is neither more nor less than the junction-line of the "moor rock" which has been converted for the time being into a land-surface, and subsequently eroded. The so-called rubbed, polished, or striated surfaces simply represent the line of junction between the coal- and shale-beds and the underlying "moor rock."

On a late excursion of the members to Giffnock some supposed evidences of movement, where the "moor rock" lies on the "liver rock," in one of the tunnels near its opening into New Braidbar, were pointed out. Their character will be best understood by a reference to the following diagram, fig. 7.

It is really, however, a fine example of extreme false-bedding, like those given in De la Beche's "Geological

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Observer," * where it is said "Diagonal arrangements of the minor parts, resulting from this pushing action along the bottom, are very common in many sandstones, as well as those which from their occasional organic contents leave little room to doubt were formed beneath the sea, as in those so frequent in many parts of the Coal-measure accumulations. These arrangements are sometimes diversified in a way to show that while some of the sandy matter has thus been forced or brushed onwards on the bottom, the same kinds of sand were at other times thrown

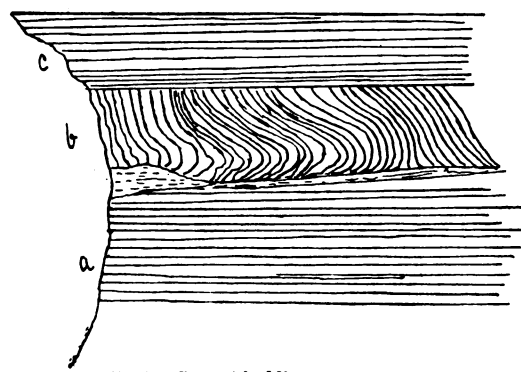

Fig. 7.—Current-bedding, New Braidbar.

[*a*, the "liver rock," forming a pillar, and *c*, the "moor rock,' forming the roof, are separated by *b*, a bed about 14 inches thick, of which the stratification is at right angles to the upper and under beds. Some observers take this as evidence of movement, the strata at *b* being bent from a horizontal into an almost vertical position.]

down in horizontal layers, more pointing to deposit from mechanical suspension." He adds that instances of this kind are not rare, and cites an example from the Old Red Sandstone of Ireland, giving a drawing which might easily stand for the section at Giffnock.

If the crumplings at Burnfield and New Braidbar cannot be accounted for in some such way, what has been the cause of this basin-shaped syncline, with its zone of contorted flagstones?

A lateral movement in the beds, resulting in the crushing of the flagstones and shales, as well as the "moor rock" and the

* "The Geological Observer," by Sir Henry De la Beche, 1851, p. 613.

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"liver rock," into a series of folds and flexures would account for them. That they have been bent is clear from the structure of the platform on which the flagstones and shales irregularly rest, for the line of junction is one of local erosion, the "moor rock" dipping with the overlying beds, and the whole being folded into this basin-shaped syncline.

In Williamwood there seems to be no evidence of the extreme disturbances apparent in Braidbar, as all the strata there dip steadily S.W. There seems to be a slight pitch of the beds towards the syncline at New Braidbar, but no sign of any contortions, from which it would appear that the beds had met with some obstacle at this point.

Westwards from the syncline at New Braidbar, and along the top of the exposure, the rocks have been disturbed for a good way. At the extreme end of the quarry, where the flagstones and the "moor rock" are first seen, the former undulate gently (see fig. 5) forming shallow synclines and anticlines, which gradually deepen as they approach the larger syncline, and show that the movement has gradually intensified from W. to E., and that the beds have been pushed against some obstacle on the east, probably an irregularity in the old platform of the "moor rock," which was sufficient to resist the general lateral movement. The maximum movement has taken place where the disturbing force has pressed inwards from its edges towards the centre of the syncline, the flagstones (fig. 6, No. 4) having been crumpled into folds whose longer axes front inwards.

The most singular feature is that the flagstones have slid between the shale-beds (Nos. 3 and 5) without affecting them. De la Beche describes a similar case at Bewley Bay, Waterford Harbour, where minor portions of certain sandstone beds were contorted, as in disturbed masses of rock on the larger scale, while the interbedded shales have slid, adjusting themselves less markedly, though their particles may have been also moved. The sliding of harder over softer beds may often be observed, as also the marks of friction produced by the movement of one bed upon another, and the striation is beautifully exhibited.

Another important point is the apparent relationship of these contorted beds to lines of local erosion. At Giffnock a strong line of local erosion underlies the crumpled sandstones and

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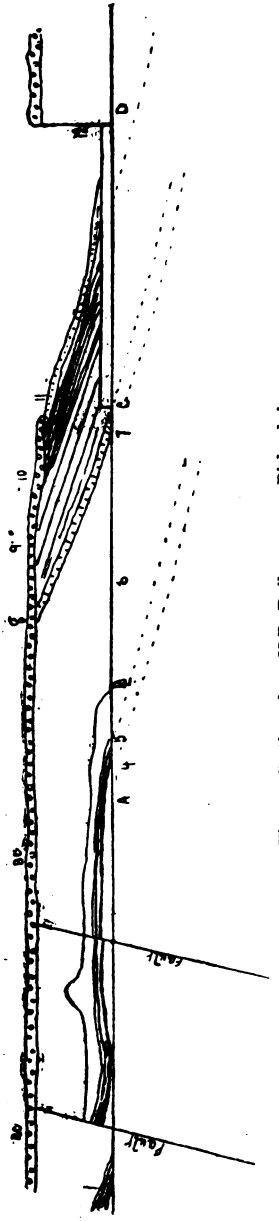

Fig. 8.—Section along N.B. Railway, near Bishopbriggs.

shales, and at Bishopbriggs beds in a similar position have also been bent and contorted. Probably therefore these local unconformities represent lines of weakness along which the beds may have been folded by lateral movements.

The same phenomenon is repeated on a larger scale amongst the metamorphosed rocks of the Highlands—the driving together and piling up of beds within the main mass, which has not in itself been subjected to the same amount of movement.

Perhaps the best example is shown by the sericite schists of Ben Lawers and the ridge N. of Loch Tay, where a mass of schist has been driven between the garnetiferous schists above the Loch Tay limestone and the overlying quartzites of Glen Lyon. Another good example is in the great precipice near the summit of Ben Lawers, and on its western shoulder.

When dealing with the Burnfield section, I spoke of its similarity to that of Bishopbriggs, and suggested that the line of local erosion above the annelid flagstones might be connected with the movement of which evidence is seen in the false-bedded sandstones below, also that there was this important difference between the two—at Bishopbriggs the upper horizontal sandstones appear to rest directly on the upturned flagstones, while at

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Burnfield evidences of movement and contortion occur considerably below the actual line of unconformity between the annelid beds and the overlying strata.

The recent exposure of the contorted beds at New Braidbar cast so much doubt on the relationship between the contortions and the unconformities that I again examined the Bishopbriggs section to determine whether an unconformity involving the upheaval and subsequent removal of several thick beds of rock actually existed there. At first I thought the movements might be of different ages, those at Bishopbriggs being, speaking generally, contemporaneous with the deposition of the beds, and those at Giffnock of later age. But I am now convinced that all the movements at Bishopbriggs are of later age than the local erosion by which they have been partly caused; that the supposed unconformities involving movements *in* the beds do not exist; and that the appearances described in the paper referred to are entirely deceptive.

The beds in the section (fig. 8) are numbered as in Prof. Young and Dr. Young's paper referred to. A strongly-marked local unconformity follows the junction of No. 5 (shales and flagstones) and No. 6 (a massive sandstone about 30 feet thick). The line of junction is very irregular; a fine sample is exposed W. of the railway, just N. of the first bridge.

Recently the removal of the overlying sandstone has, at certain points, exposed a striking view of the irregularities in the old surface of shale on which the more massive sandstones were deposited. No. 5 is of a very variable character and though generally consisting of basement beds of flagstone with shales the latter here and there replace the other rock. Sometimes the flagstones are almost vertical relative to the other beds, as can be seen E. of the cutting, and S. of the first bridge. The best example of movement is near where Nos. 5 and 6 dip below the railway level. The line of junction is very irregular, knobs of the sandstone (No. 6) protruding into the shales and flagstones (No. 5). One large boss is just where the base of the sandstone disappears below the railway level, against which the flagstones are found standing vertical.

To the left the coal-bed (No. 4) and the flagstones (No. 5) dip below the level of the railway. Above the latter are irregular

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masses of shale and flaggy sandstones evidently subjected to extreme disturbance, as they have been driven against the boss of overlying sandstone (to the right of fig. 9). An apparent line of unconformity here is entirely deceptive, and is owing to a local movement in the flagstones along a line of weakness, originally a line of local erosion.

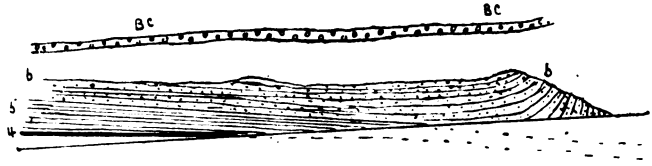

Fig. 9.—Enlarged Section in Fig. 8 from A to B.

I submit that the phenomena at North Coltpark Quarry, Bishopbriggs, described in the paper above referred to, should be read in exactly the same manner. Above the shale-beds (No. 10) which rest on the Cowglen limestone, occur patches of fissile sandstones (No. 11) which may be regarded as the base of the massive sandstones (No. 12). Here, as in the instance just described, the flagstones have been driven against a boss of the massive Coltpark sandstones (which are generally separated from the underlying flagstones and shales by a well-marked line

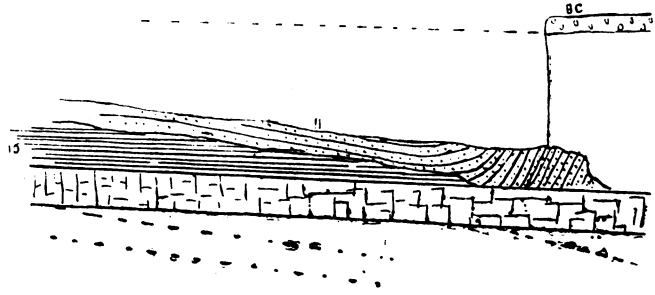

Fig. 10.—Enlarged Section in Fig. 8 from C to D.

of local erosion) the consequences being that they (No. 11) have been bent vertical. The similarity between the two instances is complete, and therefore the apparent unconformity is non-existent. The authors of the paper identified the vertical beds at North Coltpark with the fissile sandstones (No. 7) seen

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immediately below the Cowglen limestones in the railway cutting (No. 8) believing that the latter with the overlying sandstones and shales, which reached a total thickness of about 30 feet, had all been removed.

But with this conclusion I can by no means agree. I think that if a bore was put down through the vertical sandstones, the shale-beds, limestone and fissile sandstones would be found undisturbed in their respective positions.

No. VI.—The Palæontology of the Giffnock Sandstones.

One striking feature of the Giffnock sandstones is the almost total absence of organic remains. Black carbonaceous patches are found all through the strata, and most commonly amongst those with evidences of deposition near the shore-line, as for example, the "moor rock," but the plant-remains are always in such poor condition that their nature or relationships cannot be determined with any degree of accuracy.

The recent exposures at New Braidbar, previously mentioned, have, however, yielded abundant plant-remains, which are fairly well-preserved. These beds lie above the "moor rock," but are separated from it by a well-marked and comparatively long period of local erosion, when the sands of which it is formed existed as a land-surface. Above the "moor rock" lies a bed of coal in which several stems of trees, probably *Lepidodendron Veltheimianum*, have been found in an erect position.

Over this coal occurs a series of sandstones and shales, literally crammed with the remains of plants, principally ferns and lycopods. These have been examined by Mr. Robert Kidston, F.G.S., who has kindly supplied the following list:—

Asterocalamites scrobiculatus, Schl., sp.
Sphenopteris elegans, Bgt.
Sphenopteris subtrifida, Stur.
Sphenopteris, sp.
Calymmatotheca Stangeri, Stur.
Rhodea (*Sphenopteris*) *moravica*, Elt., sp.
Dactylotheca aspera, Bgt., sp.
Sigillaria Taylori, Carr, sp.
Lepidodendron Veltheimianum, Sternb.
Lepidodendron Rhodeanum, Sternb.
Lepidodendron Jaschei, Roemer.
Stigmaria.

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The commonest species is, perhaps, *Lepidodendron Veltheimianum*, and some specimens of it show the leaf-scars in very fine preservation, with, in many cases, long linear leaves attached. *Lepidophyllum* (leaves) and *Lepidostrobus* (cones) also occur amongst the shales, and probably belong to some of the lycopods named in the list. Some fine examples of *Sigillaria Taylori*, showing the scar-markings left by the detached cones, have been obtained.

As already noted, several erect tree-stems were seen during the excavation of the syncline, mostly in the lower beds, and apparently rooted into the deposit which afterwards became the "moor rock." The bed of coal lying above it marks the position of an old land-surface, and all along this line black carbonaceous material may here and there be met with. A thin bed of fireclay charged with *Stigmaria* underlies the coal, but the trees of this ancient forest were generally rooted into the underlying beds, now the sandstones, which are also full of *Stigmaria*. The markings on the surface of these erect tree-stems are somewhat obscure, so they are difficult to identify, but in one case the marks were distinct enough to show that the tree belonged to a species common in these beds—*Lepidodendron Veltheimianum*.

A most interesting palæontological feature of the Giffnock sandstones is the presence of numerous annelid burrows in the flagstones at Burnfield.

They occur in greatest number toward the top of each layer of sandstone, and die out altogether near the bottom of the thicker bands. This would seem to indicate that the annelids lived only during the period when the mud, now represented by the shale, was being laid down, and that when the change of conditions again brought back the sand deposit they either died off or were forced to migrate to a more suitable locality.

The burrows are never found in the sandstone bands solely, their trumpet-shaped mouths invariably opening into the shale, through which they pass vertically down into the sandstone, and not a single trace of them can be seen either in the sandstones above, or in the flagstone group below. The short space of time in which these organisms returned to their former quarters after the renewal of favourable conditions is

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shown in some of the thicker bands of sandstone, where rows of burrows occur, without apparently any intervening deposit of shale. On closer inspection, however, it will be observed that extremely fine layers of shale actually do exist, though only as very fine streaks.

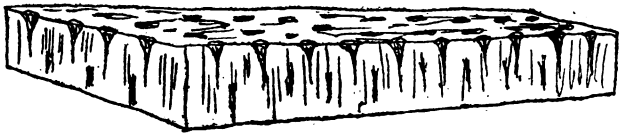

Fig. 11.—Slab of Sandstone with Annelid Burrows, Burnfield.

Fig. 11 shows a slab of the flagstone riddled with annelid burrows.

Living during the periods represented by the layers of sandy shale, like their modern congeners on our present shores the annelids had the power of burrowing rapidly through the sand and mud, and extracting the contained organic matter, much as the earthworm does in the upper soil. They passed the finer argillaceous material through their bodies in search of the minute pelagic organisms, which fall in great numbers on the sea-floor, the excreta being either voided into the burrow behind the animal, or on the surface in the form of casts like those with which some of the Burnfield beds are covered.

The annelids inhabiting our foreshores at the present day vary considerably in size, some being as much as 3 feet long, and others less than an inch. Considerable diversity also exists in the shape of their burrows, some being merely cylindrical tubes running vertically into the sand, others club-shaped, and others, again, running in loops and irregular tracks. The Giffnock burrows vary a good deal, some being 6 or 7 inches long, and others not more than 1 or 2 inches. They pass vertically down into the sandstones and open out with trumpet-shaped mouths into the shale. It seems difficult to understand how such cylindrical tubes could retain their shape so well until they were filled with the fine mud which they now contain. But Prof. Macintosh has shown that living annelids have the power of secreting an agglutinating

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slime which fixes the grains of sand together, and gives them a greater coherence. This power was probably possessed by the annelids, and their burrows would therefore remain open until the fine mud which everywhere covered the surface had been washed into them, and filled them up.

Mr. James Wilson recently pointed out to me a somewhat interesting feature in connection with the history of these annelids—that the lower beds contain comparatively few burrows, and that they gradually increase in numbers till the flagstones become literally crowded with them. Above this they begin to decrease, until they eventually die out. In the flagstone quarry the burrows are certainly fewer in the lower beds, and increase in numbers in the higher, but I have not been able to notice their dying out again. It appears to me that the flagstones have here been cut off by the strong line of local erosion previously spoken of.

Near the summit of the syncline at New Braidbar, where several beds of shale alternate with sandstones, the following brachiopods were found in the shales:—

Discina nitida, Phillips.
Lingula mytiloides, Sowerby.

The shales in which these two species occur alternate with thin bands of sandstone, which are as usual entirely destitute of organic remains, though lycopod spores and bits of scorpion skin have been collected by Mr. Bennie from the black carbonaceous patches of earthy material which occur along the line of the old land-surface.

This exhausts the list of the organic remains, so far as they can be identified, which have been found in the Giffnock sandstones.

VII.—Are the Giffnock Sandstones Marine or Freshwater Deposits?

The stratigraphical evidence seems to show conclusively that the Giffnock sandstones were deposited upon a sea-floor. The fact that they are interbedded with shales and limestones, which are in many cases highly charged with the remains of marine organisms, is sufficient presumption of their marine origin.

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It is hardly conceivable that each alternation of strata represents a withdrawal of the sea, and a return to freshwater conditions, or *vice versa*, and that not once or twice but many times.

The theory that these rocks have been laid down in fresh water can only be upheld on the supposition that they were deposited in landlocked basins, which were sometimes invaded by the sea, and at other times by fresh water, through the opening or closing of certain barriers. But a discussion of this question is beyond the scope of the present paper, and it must now suffice to say I am wholly opposed to the theory that groups of lake-basins existed in Scotland during later palæozoic times. I believe, on the other hand, that all the later palæozoic rocks were deposited against the great highland mountain mass which lay towards the north, and that an open sea extended towards the south.

In the Carboniferous limestone series, at least, no organisms of undoubted freshwater origin occur, though the presence of certain entomostracous crustaceans has often been cited as indicative of such conditions when the beds they occur in were laid down. In the face of the great weight of evidence to the contrary, it is possible that the existence of these animals may only indicate brackish-water conditions, or the proximity of land, and of river estuaries. It seems not unreasonable to suppose that the limestones, shales, and sandstones represent varying aspects of marine sedimentation, the limestones being formed on the deeper parts of the ocean bed, far enough from land to enable those animals which only flourish in pure water to live and build up the rocks by the constant accumulation of their calcareous skeletons. The shales may represent a middle zone, also highly favourable to the preservation of marine life, while the sandstones, grits, and conglomerates clearly indicate the near proximity of land-surfaces, and a formation along shore-lines unfavourable to the preservation of animal remains.

It has, however, been argued that if the sandstones are marine, some traces of the abundant life which we know existed before and after their deposition, as is proved by the presence of the abundant organisms in the shales, should still be found in them. Present day sea-shore sands are plentifully charged

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with marine forms, whereas in the Giffnock sandstones not a single trace of animal life of any kind, except the annelid burrows, has ever been got, and that notwithstanding the great facilities for search yielded by the extensive quarrying operations.

I think the presence, scarcity, or entire absence of organic remains in these rocks may be attributable to their varying preservative properties. In many of the limestones all traces of life have been entirely effaced, only masses of impure carbonate of lime being left, a result doubtless due to the percolation of water, which has dissolved and carried off the original shells, and then re-deposited the carbonate of lime along with a varying amount of argillaceous material. The finer shales seem to have been the best media for the retention of the fossils, as not only casts occur in them, but also the shells themselves are preserved in carbonate of lime, and still show minute microscopical structure. The sandstones have been the least retentive of all the rocks for the preservation of organic remains. From the very first their porous structure allowed water to percolate through the mass, and gradually to dissolve away and carry off the shelly matter in the form of carbonate of lime, while the coarsely granular nature of many of them would be against the preservation of casts of the shells.

A remarkable record of the former existence of shells in sandstone has been given in the *Transactions** by Mr. James Neilson, as occurring in cuttings on the Union Railway near Garngad Station, Glasgow. Numerous casts of *Productus*, *Spirifera*, &c., were discovered in the rock, and it is stated that "where we find only casts the space occupied by the shell is left vacant, and the muscular impressions are shown on the internal cast." These shells were all marine, but the conditions under which their casts were preserved in the sandstone are not at present apparent.

The whole palæontological evidence, meagre though it may be, thus tends to show that the Giffnock sandstones have been laid down under marine conditions. Setting aside the plant-remains, which do not weigh much one way or another, we have the annelid burrows, though it has been asserted that the animals which inhabited them may have lived in fresh water. Of course

* *Trans.*, vol. v., pt. 2, 1875, p. 226.

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there can be no positive direct evidence as to this, but it is beyond dispute that almost all water-dwelling annelids of the present day are marine, and the inference must therefore be that the old annelids were also inhabitants of the sea.

The presence of beds of shale containing *Lingula* and *Discina*, separated by thin strata of barren sandstone, also furnish some data on the point. These genera can, without doubt, adapt themselves to extremely brackish-water conditions without extinction, but they are nevertheless essentially marine forms. Are we to assume that these barren beds of sandstone represent periods of extinction or withdrawal, or do they merely indicate that the sandstones were unfitted to preserve the organic forms originally embedded in them?

Summing up the physical conditions under which the Giffnock sandstones were deposited, and beginning with the lowest, the "liver rock," it appears that this mass of rock has been accumulated in the sea at a considerable distance from the shore-line and beyond the influences of tides and currents. Then new conditions supervened, and, either by the silting up of the area, or by a slight upheaval of the sea-bottom, the action of tides and currents came into effect, and produced the irregular stratification of the overlying "moor-rock," of which some striking examples have previously been cited. In the course of time the sea became excluded entirely, and a land-surface was formed. Perhaps the most remarkable examples of this are the one at New Braidbar, immediately above the "moor rock" (and already described in detail), and that at Burnfield above the flagstone beds. With another change of conditions the land began to sink, and the ancient *Lepidodendron* forest, with Calamites and Ferns, was buried deep below a group of shore-drifted sands and muds. With a continuation of the sinking of the land we have the occasional beds containing *Lingula* and *Discina*, the maximum depression being reached during the period represented by the Orchard limestone.

VIII.—General Conclusions.

The bearing of all this evidence upon the origin of the great masses of barren sandstones found amongst the Scottish palæozoic rocks may now be focussed into one point.

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All the available direct palæontological evidence is not sufficient to establish the freshwater origin of such extensive groups as the Old Red Sandstone or the Calciferous sandstone series, but tends to show that they are of marine formation. The stratigraphical evidence is entirely against the theory of the deposition of the Old Red Sandstone in such lake-basins as those described by Sir A. Geikie, and it is wonderful the fallacies involved in it were not long ago controverted by Scottish geologists.

I am not prepared to assert that the palæozoic sandstones of Scotland were ever highly charged with molluscan remains, as it is very probable that though essentially marine they may represent shore-deposits which were constantly subjected to the influence of fresh water from the land, or to some other conditions which rendered them quite unsuitable to be the habitat of molluscan life. But admitting that they had contained such remains at one time, it is reasonable (as the evidence which has been adduced from the Giffnock sandstones goes to prove) to suppose that all traces of them have been entirely removed in the lapse of time.

Granting that the Giffnock sandstones were at one time charged with marine organisms we shall argue from too narrow a basis of fact if on that account we include all the barren sandstones of later palæozoic age in the same category. Though they are isolated and local instances, yet no one can consider the proofs here adduced in favour of the marine origin of the Giffnock sandstones, and of their accumulation under ordinary fore-shore conditions with abundant molluscan remains, and then consider the singular barrenness they everywhere display, not a single trace of a shell having ever been found in them, without being struck by this entire abscence of marine remains. So absolute have been the absorption and disappearance of all molluscan life from our limited local area, that we need not hesitate to proceed to draw a parallel from this case to others involving many thousands of feet of strata. It is but one step in the great cycle of change, through which these rocks are ever passing, and it has other parallels in geological history. We know that the deforming processes have so acted upon whole regions of fossil-

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bearing rocks as to destroy all former traces of life which they once contained, and there can be no doubt that the constant percolation of water has converted large areas and great depths of rocks originally fossiliferous into barren sandstones. Invariably the last traces of marine life to disappear are the burrows of the errant annelids, and the same rule holds good even in the great processes of mountain-building, so that when the rocks have lost nearly all traces of their original clastic structure we can still detect from the presence of these worm-tubes evidence of their original birthplace beneath the bosom of the great deep.

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No. XVI.—The Barite Veins of South-West Scotland. By John Smith. With Three Diagrams.

[Read 14th April, 1898.]

Barite is by no means a rare mineral in this part of the country, where it occurs in veins sometimes thin, but usually of more or less width, one grand example broadening out in parts to as much as 20 feet. So far as I know it is never found in beds interstratified with sedimentary rocks, but always in veins more or less vertical, and not confined to any particular rock, but intersecting igneous and stratified ones impartially. Occasionally it is got in a crystalline form in drusy cavities along with other minerals, and in the interior of fossil shells.

Of the rocks in which barite is here found the oldest belong to the Llandeilo division of the Silurian formation, as it is abundant in the mineral veins of Leadhills and Wanlockhead, Lanarkshire. I am not aware that it is present alone in these veins, though, of course, there are, strictly speaking, no veins of pure barite.

In the rocks seen in the lower part of Glen Sannox, Arran, and which probably belong to the Old Red Sandstone, barite veins occur. There are considerable veins of it in the Ayrshire Calciferous Sandstone, and smaller ones in the overlying traps. It is present in this same trap in Renfrewshire, the position being between the Calciferous Sandstone and the Lower Limestone series. In the latter rocks barite is found only sparingly in thin veins, and sometimes in crystallised form in the cavities of fossils. This is the highest horizon in which it occurs in South-west Scotland.

Barite assumes two forms, crystallised and banded, the latter being crystalline, while some varieties assume crystalline forms without being banded. At Wanlockhead in the galena and "Jack" veins some beautiful specimens of well-shaped white barite in crystals are found. In Arran those veins which are exposed in the Sannox Burn are all crystallised, mostly whitish-coloured, but some being reddish and other bluish. In some parts of the same locality the barite is brecciated, showing shearing movements since its exfiltration, but the

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major portion of the large vein at Sannox has not been broken up by earth-movements.

On the Gas Water in Auchinleck parish, about 4 miles above the Cumnock and Muirkirk road, numerous veins of barite cut through the Calciferous sandstone, one of them about 6 feet thick, and only distant from another vein about 9 feet. Both are nearly vertical and dip slightly towards each other, so that they are probably branches of the same vein, the trend of both being S.S.E. and N.N.W.

On either side of them veins are numerous, indicating a great shattering of the sandstone, but all these are less than 1 foot wide. All the veins in the bed, and on the sides of the stream, contain crystallized barite.

That the mineral has been deposited from water holding it in solution is, I think, clearly shown by some of the veins, the deposition having begun simultaneously on both sides (or walls) of the rents in the sandstone, and having ceased at the middle of the vein where a line of junction, which may be called the closing-plane, is in some instances clearly visible (fig. 1).

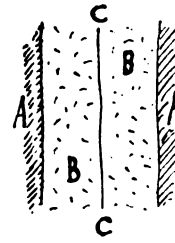

Fig. 1.—Barite Vein.
A.A., Sandstone; B.B., Barite
C.C., Closing-plane.

In some of the small veins pink barite is separated from a white variety by a sharp line. The reason is not apparent—an alteration in the chemical constituents would probably have produced a graduated change. In agates similar sharply defined differences of tint occur.

In the large barite vein before-mentioned there are nodules resembling sandstone; probably these are siliceous concretions deposited at the time of its formation; we shall meet with similar occurrences further on.

On the Gas Water, about a mile above the old race-course stables, a few veins of barite occur in sandstone, as I first saw in 1869.

Over Wardlaw Hill from the Gas Water sections, there is a vein on the side of the old road from Muirkirk to Sanquhar, which was at one time opened up, though apparently little worked. It has, in common with some other veins, the

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peculiarity of containing mammilated nodules of black oxide of manganese, some from 1 to 2 inches in size, though the debris shows nothing but crystallized barite. This vein is mentioned by the officers of the Geological Survey, but I am indebted for a knowledge of it to Mr. A. Whyte, who has some fine specimens of the manganese nodules.

On the Polwhannan burn near High Shaw occurs a thin vein of crystallized barite in sandstone, many of the crystals being free. It crosses the stream in an east and west direction.

The great vein on the Queenside moor amongst the hills between Lochwinnoch and Greenock runs N.N.E. and S.S.W., and its line is exposed for about half-a-mile. It is not perfectly straight; in parts it is perpendicular, though dipping generally N.N.W. at from 80 deg. to 85 deg. It occurs in what the Survey officers call volcanic agglomerate (but is not shown on the 1-inch map) and cuts through a number of trap dykes which trend N.W. or nearly at right angles to the vein. This fact bears directly upon its age.

For many years it has been worked both opencast and by mining. Sometimes where it opens out it presents a fine appearance, showing 20 feet of banded rock in various shades of pink, but becoming almost white in parts with very faint banding. It is all crystalline, and contains cavities or druses, generally, perhaps always, lined with crystals of barite, or quartz, or quartz and barite. Some of the barite is granular and brittle, and is purer than in other parts where it is more banded and of a closer, firmer, and stronger texture. Polished specimens show inter-laminations of quartz, and some dark specks scattered through it are black oxide of manganese. Lenticular nodules of granular quartz, like those in the Gas Water big vein, contain many well-shaped quartz crystals. Towards the centre of the vein, where it is large, there is occasionally much granular quartz banded in, and mixed up with, the barite, and these masses are put in the spoil heaps along with the nodules above mentioned.

Barite bands lie in sheets parallel to the sides of the vein, and are seen to curve round the quartz masses, showing, I think, that the latter had formed bulging prominences on the sides of the barite when it was being deposited. (See fig. 2, p. 235.)

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Some of the barite itself takes a nodular form, and occasionally free crystals of it are beautifully inter-crystallized with minute quartz crystals, and with yellow crystals of a mineral not determined.

The granular quartz sometimes looks dirty, but under the microscope this is seen to be caused by numerous crystals of dark brown quartz. A little of the massive quartz is pinkish in colour. In one specimen small quartz crystals are placed on crested barite, a form often assumed when crystallization took place in closed cavities. Beautiful masses of it are often got.

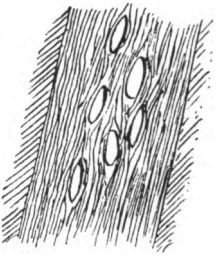

Fig. 2.—Barite Sheets, curving round quartz masses at Queenside.

An open exposure showed a curious disposition of the barite, as given in the diagram (fig. 3, p. 236), the vein being perpendicular, and 10 feet wide between trap walls.

The sides of the Queenside vein are doubly slickensided, once horizontally, and again with the dip, indicating corresponding movements. Its position is in the igneous rocks coming in between the Calciferous Sandstones and the Lower Limestones.

As to the distribution of barite in the district under review, the following may be taken as generally correct:—

On the Kilbirnie and Dalry hills thin veins of barite are sometimes found in the Trap exposed by the streams; a small one may be seen in Glen Garnock, a short way below the Castle.

Most of our Lower Carboniferous Limestone quarries show thin veins, and in the old quarry of Swinlees, Dalry, an exposure is associated, to a small extent, with carbonate of copper. In the Boghead burn, in the plantation between Muirkirk and Old Cumnock, there are thin veins in limestone, containing crystals of calcite and pyrites. In the deposits on the floor of Cleaves Cove, Dalry, crystals of barite up to 2 inches long by ½ inch thick are occasionally found, probably dissolved out from the limestone matrix.

In the Drift beds barite is often found, especially in districts where large veins of the mineral occur. The Gas Water drift contains abundance of the crystallized variety. The upper

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reaches of the Garnock, and the drift of the Surge burn have much banded barite. In the drift of the Gogo both varieties occur sparingly. Near the source of the Garnock a good deal is found, probably in near proximity to a vein.

In the Coal-measures and in the Permian rocks I have not met with any barite, their mineral veins being principally calcite, pyrites and selenite, which generally, though not always, occur in the jointings of the beds.

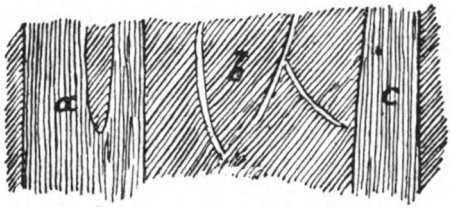

Fig. 3.—Barite and Trap at Queenside.
a, Barite, 3 feet, with tongue of Trap; *b*, Trap, 5 feet, 6 inches, with Barite veins; *c*, Barite, 18 inches.

In the Carboniferous Limestones the veins are feeble, and are confined, I think, to the Lower Limestones.

In the Granites of South-west Scotland—in Arran, and at Spango, Loch Doon, Watstone Hill and the Knipes—there is, so far as I know, none of the mineral.

The great repositories, then, of the barite veins are the Silurian, the Old Red Sandstone, the Calciferous Sandstone, and the overlying Trap rocks. Barite is probably an exfiltration product, leached out of the rocks by water, and afterwards re-deposited by the same agent in the veins, but we cannot say which of the rocks it originally was derived from.

As to its age, there is no very conclusive evidence, but the great Queenside vein, above mentioned, is undoubtedly of later date than the neighbouring igneous dykes believed to be of Tertiary age, as it intersects several of them. But though thus geologically "recent" it must be of great age as reckoned by years. From the way in which this vein outcrops at the surface, it must, in common with the adjacent rocks, have suffered great denudation, the overlying beds having completely disappeared.

In places quartz veins are found cutting through the barite ones, so they have been filled in since the formation of the latter.

It is worthy of note that in Renfrewshire and Ayrshire the

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barite veins are much thicker than those mentioned by Dana,* which are only from 2 to 3 feet thick.

At the present day salts of barium are known to be present in the water of certain springs. For instance, one of the Harrogate waters contains 7·72 grains of barium per gallon, besides other ingredients.†

* "Mineralogy."

† *Geological Magazine*, Vol. iii., 1866, page 285.

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No. XVII.—The "China-clay" Mine, and the Water-of-Ayr Hone-stone Bed at Troon, Ayrshire. By John Smith. With Four Diagrams.

[Read 10th April, 1898.]

The recent excavations for a dry dock at Troon broke in on two of the "places" of an old mine where "china-clay," so-called, had been worked. A local tradition tells that "once upon a time" some French ships used to land smuggled goods, which were concealed in the mine, and afterwards taken inland, the return freights consisting of the "china-clay," though where it went or what purpose it was used for is not recorded.

On the first visit I paid to the old mine I did not enter the workings, but noted the strata exposed as follows:—

1.	Forced Material, - - - -	8 feet.
2.	Bedded Trap, coarse grained, -	8 ,,
3.	Volcanic Dust, the "China-clay,"	6 ,,

As will be seen presently, the trap (No. 2) is probably a lava-flow or sill which has hardened the underlying bed (No. 3) at the point of contact. The latter, the "china-clay," measured 6 feet as far as exposed, the depth it had been worked to, but it went lower. It was of several shades of colour, yellowish at the top, whitish in the middle, and bluish at the bottom, and exceedingly fine in texture. Under the microscope it appeared to consist of fine granular transparent particles. It is in all probability, a finely levigated volcanic dust deposited in still water, though the lines of stratification are very faint.

Like the fireclays, it is full of slickensides, but has no rootlets running through it, as in those of the Coal-measures. It is well jointed which would conduce to its easy working. The lighter-coloured portions give a streak nearly as white as chalk. It is quite sufficiently soft to be scratched with the finger-nail, but when heated to redness in an open fire it becomes hard enough to scratch glass. In this state it is of a rich cream-colour. A few days in a closed brick-kiln give it a light grey or a bluish shade. When exposed to weather for a short time it crumbles to pieces.

On 27th March, 1897, Mr. Joseph Downs and I examined the

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mine so far as could be done on account of water. We found it had been worked on the "stoop and room" principle, the "rooms" and "rances" being 15 feet or more in width. The "stips" were very irregular, and "trees," which had been set up in the middle of the "rooms" to support the roof, were still standing.

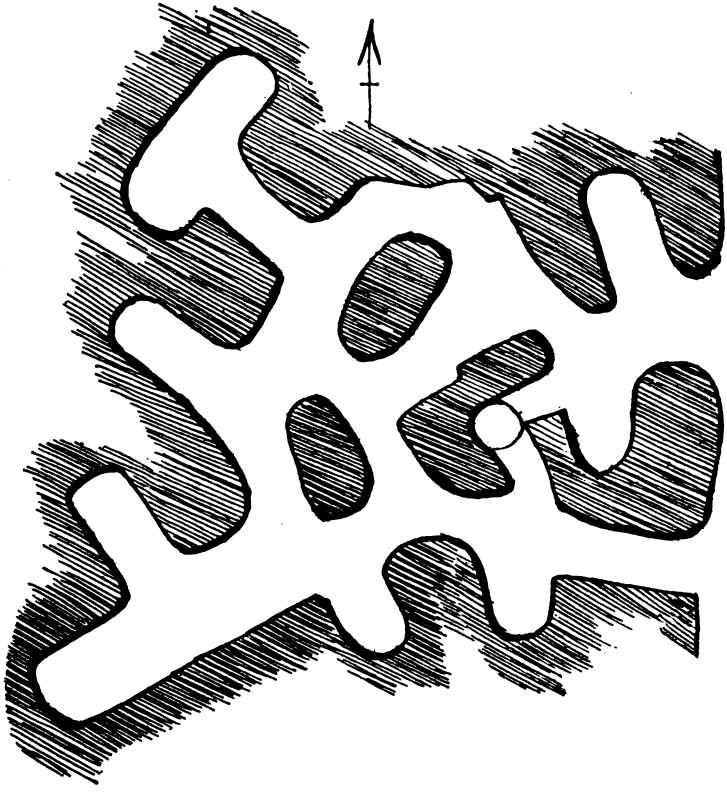

Fig. 1.—Plan of the "China-clay" Mine at Troon.

Probably we were the first to enter the mine since its recent discovery, the people about having, apparently, been afraid to do so. A few "falls" of the roof had taken place from the lowest bed of the trap, but were not large. At one "place" part of a "room" was choked up to the roof with debris,

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probably where a shaft had been put down to the clay. This "place" was only 6 feet wide, indicating, I thought, that the "door heads" had been broken away, and this was afterwards verified. The walls of the "rooms" had been carried along the master-joints of the clay, and here and there pick-marks were visible on them, as was very noticeable on the last working faces. All the rock-surfaces were covered with a fine-grained irony "glut," showing that the mine had probably been filled with water since it was abandoned. Hanging from the roof were plants apparently of a low order, their roots creeping over its surface, and these must have grown in complete darkness.

A few remains were still in the mine. There were wooden tally pins of three kinds: (*a*) plain with both ends sharpened; (*b*) with two nicks on one edge and one on the other, and sharpened at both ends; and (*c*) with the figure IV. cut out on one side, and sharp-pointed. All had evidently been used to keep count of the loaded hutches or creels, when filled by the miners. Similar pins are in use at the present day, though tallies or "counters" are now made of other materials, such as knotted string, leather (cut into a great variety of patterns), tin or copper (sometimes with cut or stamped devices). But they are all called "pins" after the original wooden pegs or pins.

A number of old boots, some very sharp-pointed at the toes, and one with tackets, were seen. This last was of the shoe type with a single hole on each side of the flap for passing a buckle-pin or a whang through. When lifted up they all fell to pieces, the sewing material having quite decayed. One boot was found on the top of a "fall," so that must have taken place before it was left.

A stake 2 feet 8 inches by 6 inches by 2 inches, and axe-sharpened at one end, was seen, besides a few odd pieces of wood including some barrel hoops. Some other "pins" were got, the wooden handle of a "creel," and a small oak wedge like those used for pick handles. But nothing turned up to throw any light on the question of the age of the mine or its contents.

My latest visits to the dock works and the mine were made in March, 1898, and I was just in time to get a measurement of the

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additional depth to which the dock had been carried. The section at the south end of the dock was as follows (fig. 2):—

	Feet.	Inches.
1. Forced Material,	8	0
2. Bedded Trap, coarse grained,	8	0
3. Volcanic Dust, the "China-clay,"	7	2
4. Volcanic Dust, bluish coloured,	0	11
5. Grey Banded Rock, fine grained,	2	0
6. Water-of-Ayr Hone-stone (so far as seen),	10	0

The great bulk of bed No. 6 is identical in structure with the well-known bed of the name, so long worked, and is of equally good quality, with the same characteristic marking or "mirl." Bands of softer texture and lighter colour run through the bed, and with fainter marking. It also contains soft and thin irregular greenish bands and nodules with a little mica and iron pyrites. The nodules are often elongated, an elliptical one being 12 inches by 4, with its long axis vertical to the bed. A few show concentric bands towards the outside, and many become quite soft on exposure to the weather.

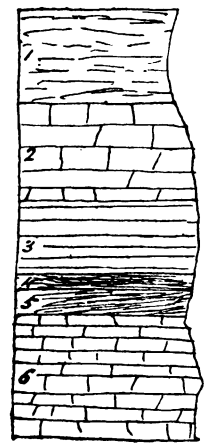

Fig. 2.—Section at South end of Dock.

Bed No. 5 shows the same peculiar "mirl" as the one below it which indicates that it probably belongs to the same series, although harder and coarser. The banding is irregular, and the bedding planes have a few particles of white mica on them.

Water-of-Ayr hone-stone has nowadays a great repute as a polisher, and this Troon stone has already gained a reputation as a whetstone amongst Ayrshire edge-tool users. A transparent section shows angular siliceous grains in position, and that the spots are made up of rings (globes with light-coloured dust centres) of black microliths. When a piece reduced to powder has the point of a magnetised needle run through it, some of the particles adhere, and under the microscope these are seen to be arranged round it like iron filings. It is probable therefore that these dark particles are magnetite and that the ponderosity of the hone-stone is due to the presence of iron in this form.

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Its peculiar mottling, earning for it the name of "snake-stone," is doubtless due to these magnetic particles, which having been mutually attracted have congregated into clusters of small globes, and were unable, in most cases, to dislodge the fine particles of light-coloured dust which form their centres.

All the stratum exposed in the dock works below the trap is probably volcanic trap in a finely divided state, which was first sifted in the air and afterwards assorted in water.

The Survey officers describe the Water-of-Ayr hone-stone as a pale grey shale hardened by trap, but it is questionable if the trap has really had any influence in this way at Troon, there being 7 feet of soft beds lying between it and the hone-stone.

At the hone works on the Water of Ayr, south of Tarbolton, Carboniferous ferns are sometimes met with in the beds, but at Troon I saw nothing organic in those below the trap. On the bedding-planes of the "china-clay" there were light-coloured markings, probably worm-trails, and on the bedding-planes of the banded bed branching and light-coloured ones, somewhat like the Silurian fossil *Nematolites*, but they may be only dendritic. (See fig. 3, p. 243.)

The trap at the north end of the dock was much thicker than that at the south end, where it had apparently cut out the stratified beds to some extent. It is the existence of this bed which has enabled Troon (Gaelic, the Point), or *Th' Trin* of common speech, to withstand the sea; at present it projects about 9 furlongs further seaward than the general coast-line.

The Water-of-Ayr hone-bed at Troon comes to the surface on the shore, south of this promontory and opposite the most westerly dwelling-houses, where it probably rests upon trap. It is in a very shivery condition but its various qualities can still be seen. One band has a "mirl" of larger pattern and more pronounced appearance than I have elsewhere met with, and had it been discovered when the old mine was opened it probably would have been quarried out to some extent, along with the overlying rocks, and Troon as we now know it would thus have been rendered unlikely, if not impossible.

That the "china-clay" exists under the trap at Troon Point seems very likely, as it is near there seen at one or two places, mixed up with trap, and converted into hornstone or porcel-

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lanite, as was also the case at the dock. When broken it shows a conchoidal fracture. The trap here presents a very rough surface from weathering. Through it run, though rarely, veins up to a few inches thick, which resemble at first sight varieties of granite, though some have a line or division along the centre, and look like exfiltration veins. Material apparently similar in composition sometimes occurs interbedded with the trap and also as lumps or nodules which are mostly composed of largish felspar crystals, and also having cavities, with hair-like crystals, probably of asbestos, stretching across them. A good deal of magnetite is present in the trap and in the veins. The trap taken from the dock was used for a wall, and was soft enough to be easily cut with a chisel.

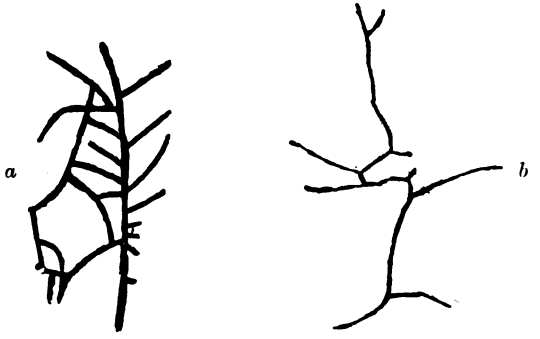

Fig. 3.—*a*, Markings on bedding-planes; *b*, *Nematolites* on Skiddaw Slates (p. 242).

No workable coal-seam has been met with in the strata of the coast district here stretching from the Irvine Water to beyond Troon, which consist of Coal-measure rocks, though they have often been bored, and the seams which have been worked in the adjoining field seem to be all more or less burned by intrusive traps, and probably also by contemporaneous lavas.

In the Ayr coal-field the workings were long ago stopped by a large fault running W.N.W. and it was then supposed that there was no coal beyond. However, pits since sunk north of the fault have proved that all the upper coal-seams occupy their regular positions, so that it is likely a large coal-field lies east of Monkton and Prestwick, and extends widely under the

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sea there. These popular watering places may, therefore, become in the near future the centre of a large mining district.

During the deposition of the "china-clay" and the hone-stone beds exposed in the Troon dock, as also of those near Carreath 3 miles E., and those on the Water-of-Ayr 10 miles S.E., there was a large Carboniferous volcano in the district, the dust thrown by it going to form the beds lying below the trap.

The hone-stone bed at Carreath was worked at one time, though the quarry is now partly filled up, but the pieces of rock lying about show that it is of fine quality. Above the dust-beds the trap is exposed to the extent of 12 or 14 feet. In it and conformable to its bedding there is a thin band of the dust, much hardened, and above, another of a few inches very much decomposed, which when seen in the quarry face resembles a bed of peat. The microscope shows the unreduced particles to be pumice, with the vesicles mostly roundish or elongated. A few are partly or wholly filled, but the bulk look as if they had been always empty. (See fig. 4.)

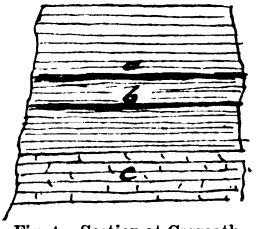

Fig. 4.—Section at Carreath. *a*, Pumice; *b*, Volcanic Dust in Trap; *c*, Volcanic Dust.

This trap decomposes very readily, and its whole face in the Carreath quarry is in a rotted state, but showing much horizontal banding, probably flow structure. At Templehill, Troon, it is also much decomposed, the material thrown out of a drain recently cut in it resembling coarse brown sand. The Survey officers regard this trap as intrusive, but the beds interbedded in it at Carreath rather point to it having been the product of contemporaneous lava-flows after the accumulation of the volcanic dust-beds below.

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No. XVIII.—Palaeozoic Radiolarians, and Radiolarian Chert. By John Smith.

[Read 26th May, 1898.]

Radiolarians were first discovered in the palaeozoic rocks by Dr. Rothpletz, who found them in siliceous shale of Upper Silurian age in Saxony. Prof. H. A. Nicholson was the first to record them from the palaeozoic rocks of Scotland, in 1890. Dr. G. J. Hinde originally illustrated the proper forms of the Scottish radiolarians from the Ordovician (Llandeilo) beds of the South of Scotland, "more particularly developed in the counties of Lanark, Peebles, and Edinburgh," and, I may add, Ayr; while Mr. B. N. Peach of the Geological Survey was the first to trace the radiolarian beds over a large extent of country.*

The chert beds had been known for a long time, but were thought to be simply shales metamorphosed into porcellanite by some unknown agency in nature. The greatest exposure of these rocks, so far as I know, is at Bennane Head, near Ballantrae, and on the shore below, where they have a width of 202 paces, measured at right angles to their outcropping edges, the outcrop being vertical.† Some years ago I made the following notes on this place:—Interlarded, or more properly speaking, folded up, with the chert, there are several beds of volcanic agglomerate containing many fragments of chert, and numerous pieces of light-grey limestone. Evidently, therefore, the former is younger than the chert, through which it must have broken up, carrying numerous fragments along with it. The agglomerate subsequently became folded up with the chert when it was turned up on edge.

The chert at Bennane Head is composed of thin nodular beds or bands of chert, mostly reddish in colour, and the rest greyish or greenish, some, however, being very dark, and almost identical with freshly-broken chalk flint. The partings of these bands are often no thicker than a sheet of paper, and

* See Dr. Hinde's paper in *Annals and Magazine of Natural History* for July, 1890.

† This great apparent thickness, is, however, caused by folding. The real thickness is supposed to be about 66 feet.

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are formed of very fine-grained material, coloured like the chert, and sometimes dusted with minute scales of mica. These partings sometimes swell out to as much as 6 inches in thickness, and are then seen to be composed of volcanic tuff, the thin ones being probably just volcanic dust. Sometimes bright-red nodules, and lenticular patches often beautifully mottled like jasper, are found, and no doubt these have been the origin of similar jaspery nodules seen in some conglomerates, and also in the drift beds.

The character of the chert itself varies from clear and flinty to dull and earthy, the difference being probably due to the sea-water in which it was deposited having been clear at one time, and at another, discoloured by sediment. The siliceous portion was, no doubt, deposited by the agency of the radiolarians from silica held in solution by the sea-water. Although the chert is as hard as flint, and strikes fire with steel, it is more easily worn away by wave-action than some of the other rocks at Bennane Head, an effect due to its numerous bedding-planes and cross-joints, and the well-known cave here has been excavated in it to a length of 30 paces. At one place I counted 36 bands of chert within 6 feet, and at another 26 bands in 3 feet, but many are of much greater average thickness. Some of these where weathered are seen to be minutely banded, and in one specimen there are 32 layers in a thickness of 2¼ inches. The rock as a rule does not split along the plane of these minute layers, but the larger ones readily separate. A large band may be quite flinty at one part, and at another dull-coloured, and closely resembling a fine-grained felstone. On the Bennane shore there are sea-stacks of chert, very "hackly-looking" piles, the strike of the beds being W.S.W.*

Within the chert area there is a patch of light-grey limestone, sometimes with reddish and greenish spots. It measures 7 paces by 6, and contains cavities bristling with crystals. The chert is seen to have undergone end-on crushing, and is often doubled back on itself. On the S. it is succeeded by

* The effect of contact metamorphism on chert by granite is peculiar, it being converted into a brown resinous, coarse-grained quartz, with brown mica, but its composition is not altered.

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volcanic agglomerate and a patch of limestone with very white veins. Then comes red dolerite and red serpentine, with, a short distance north of the main body of the chert, 9 feet of lydian stone, though this latter may possibly be only black radiolarian chert.

At the S.W. end of Craigens Hill, and 3 miles S. of Ballantrae there is a large outcrop of red chert above the sea-cliffs, much twisted and shattered, the minute cracks being filled with white spar.

On the summit of the Sowan Dod, near Wanlockhead, 1784 feet above sea-level, the long-continued exposure to the weather has brought out the structure of the chert better than at any other place I have seen. Its thin beds are seen to be just "pancake-like" nodules, if I may use the expression, several feet or yards, as the case may be, in diameter, and these in their turn are found to be aggregated masses of smaller nodules soldered or "run" together, the surfaces of the larger ones presenting a knotted appearance from the projection of the smaller nodules beyond the planes of bedding.

On Waterhead Hill, near Leadhills, some of the greyish chert outcropping on its east slope has been greatly shattered, and is now much traversed by exfiltration veins.

On Hunt Law and at the head of Glenkip, near Leadhills, the chert lying on the peaty moor has been so bleached by weathering as not to be distinguished, when seen at a short distance, from Irish chalk limestone, and myriads of radiolarians may be noticed projecting from the bedding-planes.

In May of this year, 1898, I obtained detached radiolarians from the summit of Sowan Dod, and from Waterhead Hill, in pieces of the thin layers which occur between the bands of chert, the layers at these localities having been rotted down into clay by long-continued weathering. These are, I believe, the first palaeozoic radiolarians which have been obtained in a naturally detached state. The best way to get this clay (which is decomposed volcanic dust) is to "quarry" into the looser bands of chert and remove it very carefully from the bedding-planes. Dr. Hinde informs me that detached radiolarians, with the spines attached, have been extracted artificially by dissolving certain siliceous limestones found in

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the Liassic strata of the Tyrol, and also from Devonian beds in Australia.

In the drift-beds, and more especially in the Boulder-clays, the chert boulders are usually fresher than the hill outcrops of the rock. From the Boulder-clay near Crawfordjohn I have seen a specimen of red chert with milk-white veins crossing in various directions. These are not exfiltration veins, but appear to be just parts of the chert which has lost its colouring matter in some way, and both the chert and the veins abound with radiolarians. These veins have generally a crack passing along their centres, which has probably admitted the bleaching agent.

Some of the chert contains black oxide of manganese, which occurs mostly along cracks in it, but often penetrates a short way into the solid rock, as may be best observed in the light grey translucent variety.

The Boulder-clay cherts have polished surfaces, much like the pieces of the rock found in the gravelly hollows of the Ayrshire sand-hills. The polishing is different, however, that on the former having been caused by ice-action, and that on the latter by the natural sand-blast set up amongst the sand-hills by the wind.

In the cherts examined by Dr. Hinde only the dark-coloured varieties contained radiolarians in anything like a perfect state, the others containing them only as casts.

In the chert there have been found in addition to the radiolarians numerous almond shaped hollow bodies about 1-10th of a millimetre in length, but of unknown affinities. There are also a few spicules of hexactinellid sponges, and some objects which Dr. Hinde thinks may be the tooth-plates of naked molluscs. The chert is also filled with immense numbers of minute rod-like bodies and thin flaky particles which Mr. Teall says may be rutile rods and mica flakes.

Radiolarians swarm in recent seas at depths of over 2000 fathoms. The radiolarian deposits in the Tertiary beds of Barbadoes and the Nicobar Islands were, in the opinion of Haeckel, deposited in water at quite as great a depth, so we have no reason to doubt that the radiolarian cherts of the

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South of Scotland were laid down in water at a depth of at least 12,000 feet.

In Devon, Cornwall, and West Somerset, Dr. Hinde and Mr. H. Fox have shown that there are deposits of radiolarians in the Culm measures, which they consider to be "the deep-water equivalents of the Carboniferous limestones in other parts of the British Isles." *

* *Quarterly Journal of the Geological Society*, vol. li., 1895, p. 656.

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No. XIX.—The Permian Outlier of the Snar Valley, Lanarkshire. By John Smith. With Four Diagrams.

[Read 9th February, 1899.]

This interesting patch of outlying Permian rocks, situated on the Snar Water and a few of its tributaries, has been known to geologists for a considerable time.

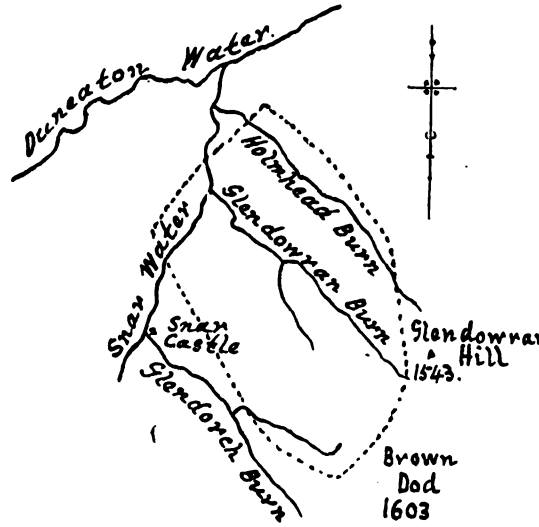

Fig. 1.—Area of the Permian Outlier in Snar Valley.

Being desirous of becoming better acquainted with such a curious chapter in the geological volume, I spent some time in April and May of last year (1898) in examining all its outcrops. It covers an area of about 1½ square mile. On all sides the outlier is surrounded by Silurian rocks, mostly on edge. This may be well seen in the Snar Water three furlongs north of the ruins of Snar Castle; on the Duneaton Water, just north of its northern boundary; on the N.E. side of Glentewing burn; in Glendorch burn on its S.W. side; and on Glendowran Hill, and Brown Dod Hill, 1543 feet and 1603 feet, respectively, on their S.E. sides. But at only one point is it seen actually in contact with the Silurian rocks, on whose

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upturned edges a small patch rests near the foot of the E. branch of Glendowran burn (fig. 2).

The outlier is well exposed on part of the Snar Water above and below Gott, on the greater part of Holmhead burn and Glendowran burn, and on nearly the whole length of the branch of Glendorch already referred to. The exposures in these streams are excessively good, showing small cliffs up to 30 feet in height, where the rock is often seen to overhang. This is owing to the fact that the conglomerate has very few joints—sometimes none being seen for many yards—so that when cut into by the burns portions do not readily fall.

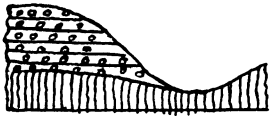

Fig. 2.—The Permian Conglomerate resting on the upturned edges of the Silurians.

On closer inspection it is seen to be entirely composed of the *débris* of the neighbouring Silurian rocks, principally greywacké, and radiolarian chert. The greywacké pebbles, which vary in size up to 2 feet in diameter, and are often somewhat rotted, are usually stained to their centres of a dirty-red colour, by oxide of iron, though some are to be found unstained, and when exposed they often show a polished, glittering appearance like that exhibited by some kinds of hematite. As a rule they are just chips of the rocks with the angles removed, although many are well rounded. A few which I saw in the conglomerate had been first rounded, then broken across, and the fractured angles again rounded before they were embedded in the matrix. The chert pebbles, although coloured on the outside, are not stained internally, except along the cracks. After long weathering they lose their surface coating of oxide, and assume their original dirty-grey or greenish appearance. They are little rounded, and are generally more solid than the greywacké rock in the hill-outcrops of the present day.

In the whole outlier I saw no shale, and only a few inches of sandstone, the great lithological feature being one uniform mass of alternating beds of coarse and fine dirty-red conglomerate. At many points there seemed to have been a lack of finer material to fill up the interstices between the pebbles,

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and the cavities have subsequently been filled by an infiltration of white calcite, which gives the rock the appearance of reddish gravel set in white marble. On the Ballantrae shore the same feature is to be seen in the local Permian conglomerate.

Wherever a crack passes through the Snar Valley conglomerate the pebbles on each side of it are seen to have lost their red colour for a short distance, and, as some of the cracks are filled with greenish or yellowish clay, they probably represent lines of faulting, slickensides being occasionally visible, sometimes with a thin crust of black oxide of manganese, which occurs in patches in the conglomerate here and there. On a vertical face of the rock I saw slickensides dipping at an angle of 45 deg., indicative of oblique movements of the beds.

The great physical peculiarity about this Permian outlier is that it dips, generally speaking, towards the hills with but few local exceptions (fig. 3).

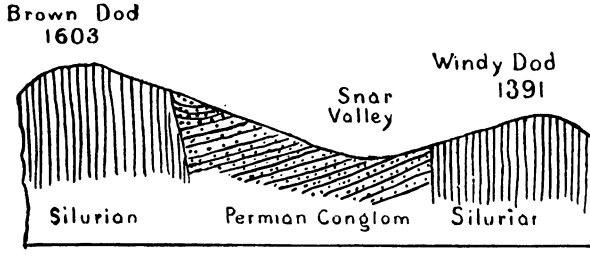

Fig. 3.—Permian Conglomerate dipping towards the hills.

The average dip may be 20 deg.—at one part I saw the beds lying flat, and at others dipping in a contrary direction at 5 deg., and up to 50 deg. or 60 deg., only for short distances. As the beds rise from a height of about 850 feet to 1350 feet above the sea-level, the difference (500 feet) plus part of the dip, would give them an enormous original thickness in the valley, but quite possibly they are now comparatively thin. The original dip could not have been, one would think, towards the hills, but in an opposite direction, this being the natural position the beds would assume on deposition. They may, of

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course, have been derived from rocks on the opposite side of the valley which were largely used up in their formation, and have since suffered immense denudation, the Permian conglomerate itself having suffered greatly since it was laid down. If its materials came from the hills towards which the beds at present dip, then they must have been tilted through an angle of perhaps 30 deg. This may not necessarily have taken place at one time, but may have been caused by a series of such movements.

That the Silurian slabs have slipped on one another is quite a common feature in this district, a good example being visible

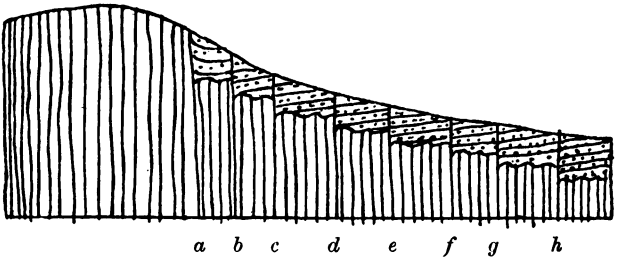

Fig. 4.—Showing how the Silurian slabs may have slipped on one another, causing faults (at *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*) in the Conglomerate.*

in a small quarry on the side of the Duneaton Water, within half a mile of the Permian outlier. Such a slipping would cause faulting in the conglomerates, which, as we have seen, are probably traversed by a number of faults. But unless this was accompanied by a tilting of the Silurian rocks, it would not account for the present dip of the conglomerates, that is, supposing they originally dipped from Brown Hill and Glendowran Hill, instead of towards them as they now do.

It is quite possible that the Permian conglomerate has been let down into the Silurians (or the latter elevated) by faults, to a considerable extent, and the reversal of the general dip at the boundary towards Glendowran Hill and Brown Dod Hill is indicative of that. At their junction with the upturned Silurians, in the branch of Glendorch burn, there is, however,

* Probably faults in Carboniferous rocks were produced in the same manner.

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no appearance of faulting, the conglomerate resting on the Silurians without any apparent subsequent disturbance. At this junction the jointing of the greywacké is stained by the red colour derived from the Permian rock for a considerable distance back from the conglomerates. In the Snar Water above Gott it is quite apparent that the conglomerate is faulted against the Silurians.

That there may be Coal-measure strata between the Silurians and the Permians in part of this district is quite possible—though apparently not likely—but this could only be tested by boring.

That the Snar Valley conglomerates are of Permian age is, after all, founded entirely on physical evidence, not a vestige of a fossil having ever been found in them, but the physical evidence is at least as good as that at Ballantrae, where red sandstones, identical with those of Mauchline, occur near the conglomerate.

It would be difficult to account for their apparent great thickness on the supposition that they were sea-shore deposits, and they are more likely to be river deposits laid down in a sinking valley, from a hilly district. The bedding is, as a rule, very good, but, where it is a little obscure, it can usually be made out by the common occurrence of the flat, board-like bits of greywacké and Silurian shales. If they are river deposits, this regularity of the bedding would seem to indicate that the stream was of considerable size. At the present time very similar deposits are being laid down in the bottom of the Dalveen Pass by the waters of the Carron.

Negative evidence is not, generally, a very powerful factor, but I may state that I did not observe any pebbles of quartz —now so common in this district—in the conglomerate, which leads to the question, Were the quartz veins and metalliferous veins of the Silurian rocks of subsequent age to the Permian conglomerate? On the other hand I saw no quartz veins passing through the conglomerate.

In what way the conglomerate received its colour is not apparent. We have seen that the Silurian strata under it are similarly stained, and it is quite possible that the conglomerate may have been stained by beds of red sandstone

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which once lay above it but have since been removed by denudation, though I think this is not likely.

In the opinion of many geologists it requires arid (rainless or nearly so) conditions to allow rocks formed of blown sand to become red-coloured, but this is quite fallacious. On the coast of Ayrshire the sand-dunes are reddish in colour, although the Raised-beach beds (and sometimes the shore sand), from which they are derived, are grey. This shows that in a very wet region blown sand may become of a red colour through the oxidation of the iron-bearing minerals. The evidence from colour, therefore, is in favour of the conglomerate of the Snar Valley having been laid down by a stream, and the deposits oxidised to a reddish colour by surface weathering.

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No. XX.—Spango Granite. By John Smith.

With Five Diagrams.

[Read 9th March, 1899.]

The Spango Granite mass lies between Crawick Water, Duneaton Water, Spango Hill, and Mount Stewart, in Lanarkshire. The exact outline of its boundaries cannot be traced, as the surface is so much covered by peat-mosses that the rock itself is exposed at few places, and it presents neither peaks nor hill-crags to pierce the covering (fig. 1).

At no part of the area did I find the ground clear enough from vegetation and *débris* to allow of an examination of the

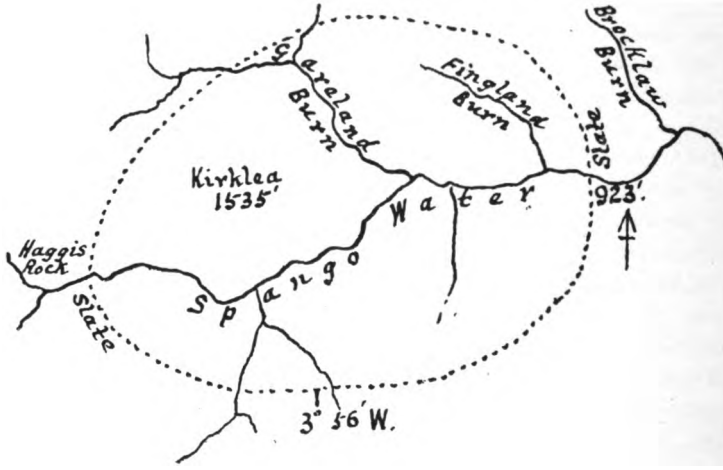

Fig. 1.—The Granitic Area is within the dotted line.

junction of the granite with the adjacent rocks. On the eastern side it must be about 200 yards east of where Fingland burn joins Spango Water, 923 feet above sea-level, and the lowest level at which the granite is seen *in situ*. Here a large outcrop of grey "slate," not unlike some of the Arran slate, is seen, partly in place close to the granite, but mostly as detached boulders on the lower slope of Fingland Rig, where thin veins of fine-grained granite pass through the slate.

A little way west of the slate outcrop the granite is exposed to some extent in position, but mostly as a great mass of blocks, on the hillside, where several springs of water issue from it.

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There is also a considerable outcrop of the granite, both reddish and greyish, between the slate outcrop and the mouth of Fingland burn.

This burn and the gills running into it are good places to study the effects of weathering on the granite. In a side gill a 12 feet section of rotted granite is seen, the water running over the solid rock below. It clearly has rotted here in position, and its characteristic jointing is brought out even better than in the solid granite. At other places the rotted granite resembles banks of soft, brownish sand. In some of the gills balls and great nodules of undecomposed rock are seen *in situ* amongst the rotted granite or arkose. A study of these will show, I think, that they are not mere portions of the rock unaffected by decomposition, but that the granite itself is essentially different, and that this is proved by the fact that the nodules themselves are sometimes rotted through, or partially rotted with undecayed centres (fig. 2).

At a small waterfall near the mouth of Fingland burn there is an exposure of solid reddish granite, and near it what is evidently a line of fault, the rock being slickensided, and its felspar converted into porcellanite, doubtless from heat evolved by the friction. Not far W. of the eastern outcrop granite is seen in the bed of the Spango, and, contrary to what might be expected, the blocks in place present sharp edges on their upper surfaces, caused, probably, by gravel rolled down the stream during floods, the first impact against the blocks wearing away their sides, though afterwards there seems to have been comparatively little effect produced.

Fig. 2.—Rotted Granite Nodules, some with solid centres.

On Spango Water, 200 yards above its junction with Fingland burn, granite in slabs is seen in position, and dips W. at about 80 deg. Near the same place the granite also occurs in detached pillars—the effects of weathering. (Figs. 3 and 4, pp. 258 and 259.)

Above Gareland shepherd's house the valley widens out, and

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between that place and Blackgannock, slabs of dark-coloured granite dip E. at about 80 deg. A short distance further up the burn the slate is seen in position, so that its junction with the granite must be hereabouts, though no exposure of it is visible. Opposite Fingland shepherd's house, which is situated on a mound with a ditch, the position being apparently that of an old fort, on the left bank of Spango Water, the "Haggis Rock" is seen in position—a conglomerate of great toughness, made up of small pebbles of quartz, lydian stone, &c.

In Gareland burn—flowing over the granitic area for some 2 miles—no massive granite is exposed, but at the base of Liffshaw Hill there is a coarse-grained granite vein 1 foot wide in the slate, which has the peculiarity that it breaks easily into splintery fragments, somewhat like the enclosing slate. This slate—where not rotted, as it usually is to some depth—is soft, bluish in colour, and contains glittering specks of iron pyrites between it and the adjoining granite.

Going up Gareland burn from this point we meet first with dull-purple shales, and afterwards with great high crags of dull-purple felstone conglomerate which extends for a considerable distance, the well-rounded blocks in it reaching up to a size of 3 feet in diameter. It is not always a simple matter to determine the dip of a conglomerate, but this one seemed to me to dip W. at the high angle of about 80 degrees. If this observation is correct, it may perhaps show what influence the granite has had on the dip of the rocks at this place, but still it is more likely that the dip is owing to the close proximity of the great boundary fault.

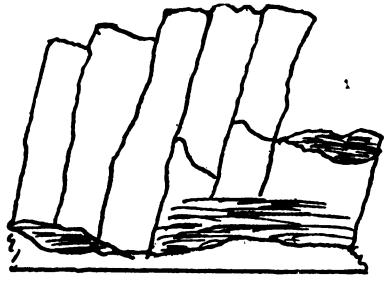

Fig. 3.—Granite Slabs, the whole about 13 feet wide. (See p. 257.)

In trying to work out the relationship of the granite slabs to the surrounding rocks possibly not much can be made of their dip, as they are exposed at only two places, viz., near the E. and W. boundaries of the granitic area, but it is worth

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noting that at both places the slabs dip towards it—which is peculiar, and different from the way they dip in Arran. The width of the area here is about 21 furlongs from E. to W., while in the opposite direction, N. to S., it cannot be so exactly determined, but is, probably, somewhat less. I may remark that the strike of the granite slabs, where exposed, does not conform to that of the Silurian rocks, but the dip angles of both are equally high.

In the Spango granite I saw no inclusions, and in this respect it agrees with the granite of Arran, which, so far as I have seen, is also free from them. But it thus differs from the granite of Loch Doon, where nearly every block has one or more inclusions. On the west slope of Spango Hill, where the rock is Silurian, there is a great mass of large boulders;

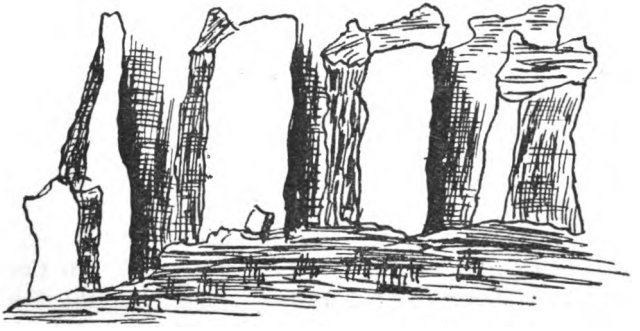

Fig. 4.—Spango Granite in the form of Pillars. (See page 257.)

and this is the more remarkable, as the greywackés of the district seldom furnish large blocks. Perhaps the influence of the granite had something to do in hardening the rock here. It is difficult to decide whether these blocks have been moved and worn during the drift period, or are the remains of rock weathered *in situ*. Spango Valley, right up to the granitic area, appears to be choked with drift of some depth, and on the granite itself, both of the "Spank" (the native pronunciation of Spango) and its principal tributary, Gareland burn, there may be much drift in the bottoms of the valleys, although little appears above the level of the streams. Between Brockley burn and Fingland burn, on the left bank of the Spango, and

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not on the granitic area, though near it, there is a bank, 20 feet high, full of boulders, mostly of granite, and as water flows over the top of the bank, it is likely to be Boulder-clay.

On the granitic area there is very little drift to be seen, but at certain parts there are great accumulations of granite boulders. A mass near the eastern boundary has already been noted; on the right bank of the Gareland burn, near its mouth, there is another mass; half a mile below Gareland shepherd's house, on the left bank of the Spango, there is a great mound of blocks; on the south-western side of Bught Hill there are many; at the base of the same hill, and below a fresh-looking "sheugh," a great many boulders are seen lying on the level ground at the hill-foot, where they have, perhaps, been conveyed by a waterspout. The hill-side being pretty steep, such a force seems quite adequate for the work, and the blocks have, to all appearance, come out of the "sheugh."

Outside of the granitic area Spango granite is found in all directions in the shape of boulders; in the Spango Water down to its junction with Crawick Water, 780 feet above sea-level, they are in the greatest number. But this state of matters will not always remain, as when I was there they were being broken up and carted away for building purposes. They are mostly pale red in colour, the outside surfaces being of a ruddier hue than those of freshly-broken faces. In Crawick Water, both above and below its junction with the Spango, there are many blocks; in Wanlock Water they occur sparingly, up to at least 920 feet; Duneaton Water, and its tributary, Sheriffcleugh burn, have blocks up to 4 feet 6 inches in diameter, those in the latter lying on felstone.

On the granitic area I saw a few foreign blocks, consisting principally of greywackés and traps, the latter, perhaps, being derived from dykes traversing the granite, though I saw none during my examination.

Going further afield we find Spango granite in Glendyne, and to have reached that place in a straight line it must have come over ground just a little lower than the highest part of the granitic area, which at Kirklea Hill is 1535 feet above sea-level. Of course it may not have come straight across country. In the thick drift of the lower reaches of the deep

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narrow valley of Cog Water there is some Spango granite; on Mount Stewart, at 1250 feet, there is some; as also in the valleys of the Guelt, the Glenmore, the Douglas, and the higher reaches of Ayr Water; so that it seems to have been dispersed from the massive rock in all directions.

These Spango granite boulders are called "Beerman" by the natives, which is probably a form of, or corruption of, the Gaelic word for *hill-blocks*.

In the solid granite I saw no fine-grained veins, but in the boulders I detected a few.

Lying in Kiln or Orchard burn, a branch of Crawick Water, there is a famous granite boulder of large size, known in the country-side as "Mungo Girr." It measures 13 feet long by 5 feet 8 inches wide, by 7 feet high, and has two veins of

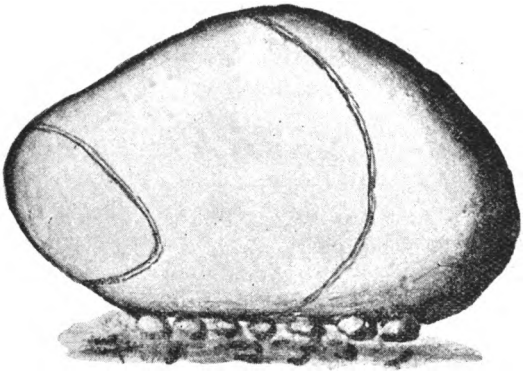

Fig. 5.—Granite Block, "Mungo Girr," with two fine-grained veins, in Kiln Burn

fine-grained granite running through it and projecting from its surfaces. There is a local tradition that it once rested on the top of a neighbouring hill, and one day when a dishonest packman called "Mungo Girr" was sitting on the big stone, the devil gave it a kick and sent it rolling to the bottom of the glen where it now lies. The unfortunate packman was, of course, killed, and the veins which we still see projecting from the boulder are believed to be his petrified entrails. The name is probably a corruption of the Gaelic for "the stone with the 'girr' or band." I did not ascertain whether this boulder is Spango granite or not.

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From what we have seen as to the nature of Spango granite it is quite possible that the great bulk of the boulders were weathered into shape and ready for transport long before the glacial epoch, so that although most of these we see scattered over the surrounding country are well-rounded, we cannot attribute their shape, with any certainty, to the attrition they may have undergone by the action of the ice-borne material.

If all the decay observed in Spango granite (12 feet deep in one section, without the undecomposed rock being seen) has taken place since glacial times, it must have rotted at a comparatively rapid rate compared with some other granites. Messrs. Kinahan and Nolan have estimated that the granite of Oughterard in Ireland has decayed only to the extent of ½ inch to 1½ inch since glacial times, their calculations being based upon the height that unweathered veins stand up above the mass of the rock which they traverse.

Redscar Heugh is a prominent feature in the lower reaches of Spango Valley, where the stream has cut sideways into Spango Hill since the glacial period, and has exposed a great corrie of splintery, rust-coloured shale of Silurian age.

As already remarked, the hill-tops in the Spango granite area possess no rocky peaks, nor even exposures of the solid rock itself, and when viewed from a distance their contours so closely resemble those of the neighbouring Silurian hills that there are no salient features by which the geologist can distinguish them from those of the surrounding greywackés.

The "great boundary fault," which traverses the full breadth of Scotland from sea to sea, passes along the northern edge of the Spango granite mass, which is probably "thrown" by it.

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No. XXI.—Note on a Microscopic Slice of the Core of the Dalmeny *Lepidophloios.* By James Bennie, *of the Geological Survey of Scotland.*

[Read 26th May, 1898.]

The tree trunk from which this slice was taken was found in the railway cutting on the Forth Bridge extension of the North British Railway, near Wester Dalmeny, by Mr. Thomas Kerr, inspector, and was placed by him on the platform of Gorgie Station, where I first saw it. I recognised it at once as a Carboniferous tree, similar to those I had seen at some of the ironstone pits near Glasgow, but much larger than any of them, several of the pieces being about 14 inches in diameter, and 7 or 8 inches in thickness.

The outside bark was intensely black where perfect, and yellowish where scaled by weathering. Inside the bark was a layer of white chalky-looking material, with a circlet of black matter within it. On examination with my lens I found that the latter consisted of a lacework of cells, with lines radiating from the centre, which showed it to be the core of the tree, the structure being preserved as in life. I therefore thought that the specimen would be a prize for the Geological Survey collection in the Museum of Science and Art in Edinburgh. But to make quite sure that I was right in my identification I asked Mr. Robert Kidston, F.G.S., to go to Gorgie and see the tree for himself. On his visit Mr. Kerr handed him over the specimen, and he at once took possession, and carried it off to the marble-cutting works of Messrs. M'Glashen & Sons at Canonmills, to be cut and polished. This they did admirably, and not only was the character of the tree as a Lycopod made clear, with its core or heart, but the chalky matter underlying the bark was shown to be volcanic ash, and to consist of pellets and dust, such as were thrown out of the small volcanic necks or vents which pass often through the Carboniferous rocks.

The history of this tree might be read thus:—It had once been sown as a spore by the wind in good soil on Carboniferous ground, where it had grown and flourished until it became a stately tree of about a foot in diameter. Then through

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natural causes, or from the effects of some catastrophe it had died, and afterwards decayed till all the soft interior had rotted away, when the upper portion of the trunk fell over, leaving the remainder standing as a hollow stump. Then at some subsequent period showers of ash, ejected by a neighbouring volcano, had filled it up to the top, the core having apparently fallen or been pushed over to one side. The stump had then fallen down, and petrifaction setting in the whole was turned into stone, with the organic structure of the remaining tissues thoroughly preserved through infiltration of silica and lime.

The only other noticeable feature of this specimen which need at present be mentioned is the occurrence through the vascular network of the outer part of the core of numbers of circular patches, probably composed of silica, and which, in all likelihood, have been produced by some process of concretionary action.

Note.—This specimen has been fully described by Messrs. A. C. Seward, M.A., F.R.S., and A. W. Hill, B.A., in the *Transactions of the Royal Society of Edinburgh*, vol. xxxix., pt. iv., No. 34, 1900 (pp. 907-931, plates i.-iv.).

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No. XXII.—Goldmining in the Sierra Nevada, California.

By R. W. Dron, C.E., M.E.

[Read 13th January, 1898.]

[Abstract.]

In the course of his remarks the author stated that the first discovery of gold in California was in 1848, when a workman picked up several large nuggets out of a mill-race which he was digging. In 1850 the first quartz vein was found by some miners who were digging a hole for their cabin chimney, and was so rich that some of the pieces of ore taken from it were sold for £100 each. This state has long maintained her position as the greatest gold-producing state in the North American Union. The production just now is valued at £3,000,000 per annum, and the total value of the metal recovered since 1848, at £260,000,000.

The rocks of California are divided into two series, the bed-rock, and the superjacent rock. The bed-rock series consists of highly altered sedimentary strata, crystalline schists, and slates, with intrusive igneous rocks, mostly belonging to the Carboniferous, the Jurassic, and the Triassic formations, and resembling the metamorphic Jura-Trias rocks of the Alps. From an economic point of view the most important feature of the bed-rock series is the occurrence of veins and lodes containing gold, silver, &c., and perhaps the most interesting of these is the formation known as the "mother lode."

This "mother lode" is contained in a series of black schists and slates, with a dip to the E. of 20 deg. to 40 deg. from the vertical. The veins are found in a fissured area a mile or two wide, which stretches throughout a length of 120 miles, from Mariposa, in the south, to Colfax on the Central Pacific Railway, in the north. They have generally a dip E. at almost the same angle as the slates, and have the appearance of stratified deposits, although there can be little doubt they occupy true fissures. The gold only occurs in certain portions known as "pay shoots." While it is beyond doubt that the veins of the "mother lode" extend downwards as far as it is possible to mine them, it does not necessarily follow that each "pay shoot" continues uninterruptedly downwards. Occasionally they die out, or become very small, but

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when this happens a new "pay shoot" can generally be found by driving tunnels, or by deepening the existing shafts. In a few mines the ore has become richer as the workings extended deeper, and this has caused the misleading theory to be advanced, that the same happens in all cases, but there is no scientific evidence to warrant this assumption.

The total cost of working and milling the ores varies from 10s. to 20s. per ton, and veins containing only a few dwts. per ton are thus being worked out at a profit. Some mines are producing ore containing as much as 4 oz. of gold per ton, but the general average seems to be from 10 dwts. to 15 dwts. per ton. The ore is crushed in the usual form of stamp battery. The free gold is recovered on amalgamated copper plates, and the sulphurets are concentrated by means of vanners. These sulphurets after concentration have a value ranging from 40 dollars to 500 or 600 dollars per ton, and the gold is recovered by the clorination or the cyanide process.

The superjacent series of rocks belongs to the Later Tertiary period, and consists of large deposits of almost entirely white quartz gravel, covered over by volcanic flows, the gravel beds having been deposited by ancient rivers. Some of the original deposits are 150 feet thick and over a mile wide, and can be traced for miles along the old river channels. The hard lava-cap has preserved them from the usual disintegrating influences, with the result that, while the surrounding country has been eroded to the extent of from 1000 to 3000 feet, the gravel beds have been left intact, and are now found near the summits of the lava-capped ridges.

Prior to 1880 the larger gravel deposits were worked by the hydraulic method at a cost varying from 1½d. to 6d. per cubic yard. The large amount of sediment washed down into the San Joaquin Valley and the Sacramento Valley by this process caused the river to be partly silted up, and a great outcry was raised by the agricultural population. This resulted in the passing of a law, about 1880, whereby hydraulic mining was entirely prohibited, unless under exceptional circumstances.

Mines are still worked in the old channels, but only the richer gravel is extracted. The cost varies from 4s. to 12s., and the yield of gold from 1½ dwts. to 15 dwts., per cubic yard.

The paper was largely illustrated by diagrams and specimens.

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No. XXIII.—Geological Time. By J. G. Goodchild, F.G.S., Curator of the Geological Survey Collections in the Museum of Science and Art, Edinburgh.

[Read 27th January, 1898.]

[Abstract.]

The author began by making some observations upon astronomical distance, pointing out that as astronomy had been recognised as a science from an early period in the history of civilisation we had nowadays all become more or less familiar with the conception of vast intervals of space. Geology, on the other hand, was a science of very recent growth, and had hardly yet passed through stages of development which had been reached by astronomy 2000 or more years ago. While, therefore, no rational person was prepared to call in question statements regarding the distances of even the nearest of the stellar bodies, there were many who had failed to realise any true conception of what was meant by "geological time"; like those folk who, centuries ago, opposed the statements of astronomers in regard to vast intervals of space, these now dissented from the statements of geologists in regard to equally vast intervals of time. This, of course, was partly due to the fact that many of the data with which the geologist had to deal had not yet reached the stage of exactitude to which astronomical data had attained in the middle ages. Other reasons, obvious to any thoughtful person, also stood in the way.

The lecturer then dealt with some of the evidences which lead the geologist to consider that vast, if still indefinite, periods of time are implied in the development of events in the earth's past history with which it was his special province to deal. He was emphatic in his statement that a period nothing short of several hundred millions of years was required to account for the changes which have taken place on the earth since the commencement of the Cambrian period, and that the close of what has been termed the astronomical history of the earth was remote from that time by a period perhaps equally vast.

One of the several illustrations in support of this view

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related to the rate of decomposition of rocks of eruptive origin, such as granite and dolerite. Under humid conditions these rocks wasted by the decomposition of the silicates of which they chiefly consisted, and this was effected by the action almost wholly of surface waters charged with carbonic acid. Hornblende, augite, and allied minerals absorbed in the process of this decomposition about one-third of their weight of carbonic acid, so that three tons of any one of them, which represented the weight of a cube slightly more than a yard on each side, absorbed about one ton of carbonic acid from the atmosphere.

As the whole atmosphere over each square yard of the earth's surface only contained about ten pounds weight of carbonic acid, and as the supply of this gas was never very high, it was obvious that the rate of decomposition could only keep pace with the supply of this essential agent, and therefore could never proceed at more than a very slow rate. Indeed, if it were not for the fact that carbonic acid was being returned to the atmosphere mainly through the action of volcanoes (at the bases of which the carbonates were undergoing conversion into silicates, with the consequent liberation of carbonic acid) the decay of the eruptive rocks would soon come to a standstill.

Mr. Goodchild's other illustrations related to the rate at which marine limestones were being formed (one foot in 25,000 years) and to the rate of general denudation, the latter being considered at some length in connection with the subject of unconformities.

A number of illustrative slides were shown by the oxy-hydrogen lantern.

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No. XXIV.—The Bearing of Fossil Ichthyology on the Doctrine of Evolution. By R. H. Traquair, M.D., LL.D., F.R.S., Keeper of the Natural History Collections in the Museum of Science and Art, Edinburgh.

[Read 24th February, 1898.]

[Abstract.]

The lecturer pointed out that it had been urged against the doctrine of descent by Hugh Miller and others that the oldest fossil fishes we know are the remains of creatures of high organisation, and not of a low or primitive type. But we cannot accept the fishes of the Upper Silurian or of the Old Red Sandstone formation as the oldest fishes which ever lived, as the most primitive ancestors of the class of fishes could not have possessed any hard parts which were capable of preservation in a fossil state.

The palæontological record was also very imperfect from other causes, and therefore afforded us only very disjointed glimpses of the history of organic life on the globe. Many anti-evolutionists had not been able to differentiate the idea of highness and lowness of organisation from that of generalisation and specialisation of structure. The old sharks and ganoids of palæozoic times were doubtless more highly organised as animals than the mass of the fishes of the present day, but they were not so specialised as fishes. They were animals of "generalised" structure, having, as it were, the potentialities of higher development in them, and in all probability, the amphibia, and through them the higher vertebrata, had their origin from the palæozoic Crossopterygian ganoid fishes.

Thereafter as the higher vertebrata evolved, the class of fishes became more and more specialised in a direction of their own, while they tended to lose the characters which linked their ancestors and the few surviving representatives of their ancestors to the amphibia.

In illustration of the process of specialisation of various groups of fishes a very large and fine series of lantern slides was exhibited. Particularly interesting were those showing how, as M. Dollo of Brussels has pointed out, the living Dipnoi, or "lung fishes," have probably been evolved through *Dipterus*

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from the ancient Holoptychiidæ. The line of descent of the modern bony fishes was shown to have been probably from the ancient Acipenseroids (Palæoniscidæ) through the Lepidosteoid and Amioid forms of the mesozoic periods. The gradual change of the tail from the heterocercal to the homocercal form was also shown in a selected series of slides, concluding by demonstrating how in modern homocercal fishes, as the flounder, the tail is heterocercal in the embryo.

It was strange that Agassiz, though the first to call attention to this significant fact, was an anti-evolutionist to the end of his life. But not only has knowledge increased since his time, but people's ways of looking at things have also changed, so that whether we believe in Darwin's theory of natural selection or not, the doctrine of descent is now accepted by the great majority of living naturalists.

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No. XXV.—The Dolerite of Aberdour, with some Speculations on the Origin of Eruptive Rocks in general. By J. G. Goodchild, F.G.S., Curator of the Geological Survey Collections in the Museum of Science and Art, Edinburgh.

[Read 26th May, 1898.]

[Abstract.]

In the course of his remarks the author stated that the dolerite of Hawk Crag, Aberdour, forms a sill which is intrusive in beds belonging to the lower part of the Oil Shales of the Lothians. It shows ophitic structure in its central portions, but passes into basalt or tachylite, where it has been chilled by contact with the cooler rock into which the mass was erupted. Near the more carbonaceous bands the eruptive rock passes into "white trap"—the "white horse" of the miners of the West of Scotland—a phenomenon probably due to the partial reduction of the iron oxides present in the cooling rock effected by the carbonaceous matter. Certain parts of the dolerite interdigitate with strips of the associated rock of sedimentary origin in such a manner as to suggest that here, as in so many other cases, the eruptive rock has replaced portions of the mass.

Many instances in which similar phenomena are to be seen were passed in review in the course of the paper, and Mr. Clough's explanation of these, as due to slow assimilation of the sedimentary rock by the eruptive magma, was referred to at some length. In further explanation of the occurrences in question, it was suggested that the difficulties met with in attempting to account for the behaviour of many intrusive masses, and most especially those of deep-seated origin, might be met by assuming that water charged with alkaline solutions, operating under great pressure, and at temperatures such as that attained by the H_2O in lavas, had slowly dissolved the sedimentary rock, equalised its composition by an equally slow process of diffusion, and had subsequently deposited the dissolved compound in the crystalline form as the temperature fell.

The employment of the term "laccolite" for any intrusive mass, except such as actually displaces the whole of the rock

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invaded, was protested against. It was contended that such phenomena are of rare occurrence, and are restricted to rocks which have been intruded under small super-incumbent pressure, such as occurs in the case of volcanoes.

The paper was illustrated by maps and diagrams.

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No. XXVI.—The Problem of the Marginal Highlands. By Peter Macnair.

[Read 13th October, 1898.]

[Abstract.]

The "Marginal Highlands" the author defined as the area lying immediately to the north-west of the great line of fault which separates the Old Red Sandstones of the Scottish Midland valley on the one hand, from the crystalline rocks of the Highlands on the other.

The writings of Murchison, Geikie, Harkness, Jameson, and Nicol upon the district were first reviewed, as well as the more recent work of the officers of the Geological Survey, including the lately issued memoir of "The Geology of Cowal," and the present position of "the problem" was stated to be as follows:—(1st) Is there any evidence of the interposition of a belt of Lower Silurian rocks along the margin of the Highlands? (2) Are those grits and phyllites, which are seen dipping below the schists towards the east of the mountain chain, in their correct position, and do they overlie the schists of the interior, as seen in Cowal and on the N. shore of the Firth of Clyde? (3rd) Is there any evidence in Cowal to show that a great anticline of the foliation exists, and crosses an early syncline in the bedding?

The author then proceeded to enumerate six schist zones into which the rocks under review might be divided, grouping together their larger lithological features, and pointing out that they were capable of still further sub-division. He described a number of sections taken across the Highlands from Bridge of Cally on the E. to Dunoon on the W., and endeavoured from these to obtain a key to the true structure and succession of the rocks. Finally he weighed the whole evidence brought forward, and gave the following conclusions which, he submitted, were at least tentative answers to the questions arising from "the Problem of the Marginal Highlands":—

(1st) There may exist a belt of younger rocks wedged in along the Highland frontier, probably of Arenig age, as maintained by the officers of the Survey; but there seems to be a difficulty in separating them from the great zone of phyllites and grits which

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undoubtedly form part of the main mass of the Highland schists of the interior.

(2nd) To the E., as in the districts of Dunkeld, Crieff, and Callander, the dip of the limb of the fold, as indicated by the arenaceous strata, is towards the N.W., at an angle varying from 40 deg. to 50 deg., and the rocks pass conformably upwards into the higher schists of the Central Highlands. On towards the east end of the mountain chain the amount of disturbance and metamorphism has been comparatively small. Passing S. and S.E. at Aberfoyle, and at Lochlomond, the dip of the limb of the fold becomes almost vertical, and shows an increasing metamorphism of the slates and grits, with lines of weakness, or crush-planes, along which the rocks have been forced. In Cowal and on the N. shores of the Firth of Clyde the southern limb of the rock-trough has been bent over and pushed inwards upon the main mass of the Highlands, so as to form a recumbent syncline with its axis heading S.E. at a low angle.

(3rd) We have thus what appears to be the most likely solution of this difficult problem—as advanced first by the writer in 1896—that the principal foliation has been coincident with the bedding, and that the apparent anticline in the bedding described by the earlier geologists, and of the foliation as maintained by the officers of the Survey, are entirely deceptive.

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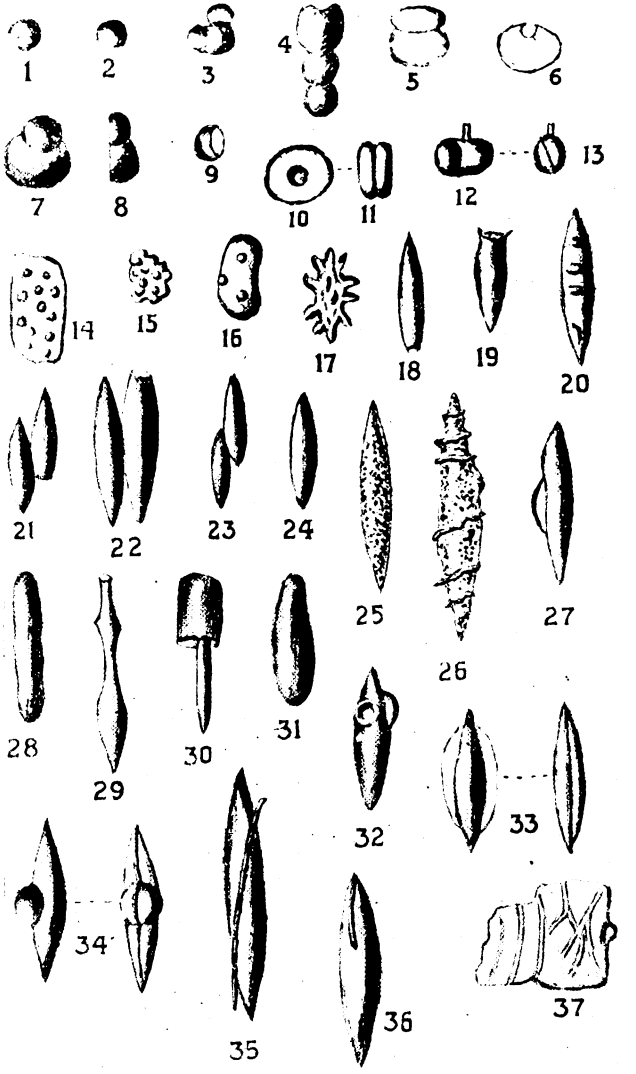

Microliths in Arran Pitchstone.

J. Smith, del. *Hislop & Day, Photo Engs.*

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No. XXVII.—Detached Microliths from the Pitchstone Sill at Corriegills, Arran. By John Smith. With a Plate (No. XI.).

[Read 10th November, 1898.]

The Great Pitchstone Sill at Corriegills has often been examined and described. Bryce in his "Geology of Arran" (3rd ed. 1865, p. 70), says, "There is no remarkable change [produced by the pitchstone] on the sandstone—a slight induration merely—but the lower portion of the pitchstone is changed into a blue-coloured, porous, slag-like matter, like a pumiceous lava; this, however, is probably the mere result of decomposition."

That the pitchstone has been decomposed by percolating water finding its way between it and the sandstone—and which still oozes from that quarter—I think there can be no doubt, but I can see no resemblance in the decomposed part to the so-called "slag-like matter."

The following is my measurement of the bottom part of the pitchstone sill here, at a part of the cliff where it is easily accessible, its total thickness, according to Bryce, being 13 feet 5½ inches:—

1. Red Sandstone.
2. Pitchstone, laminar and columnar.
3. Pitchstone decomposed, but laminar, 5 inches.
4. Pitchstone decomposed, laminæ not visible, joints still seen, 7 inches.
5. Pitchstone decomposed into yellow clay, neither joints nor laminæ, 5 inches.
6. Red Sandstone.

No. 3 can be dug out in thin layers which contain many irregular cavities caused by decomposition. When dry it is greenish in colour, and many white microliths can be seen in it with a pocket lens. Its surfaces are covered with minute circular patches which, where they run together, form figures like those seen on the polished surfaces of some jaspers. The intermediate spaces are filled up with numerous minute lines which cross one another like oblique shading or "hatching," but they are by no means straight, and are only roughly parallel to each other. They are of a pale green colour on a dirty white ground.

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No. 4 can easily be reduced to clay if dried and washed, or even if squeezed between the fingers. It contains a much greater number of the microliths than any of the other bands.

No. 5 has very few microliths to be seen in it, most of them having probably been removed by decomposition, but it contains a few forms which have not as yet been detected in No. 4.

Whether the curious and varied forms of the microliths are entirely the result of decomposition, or are previously existing forms which have been weathered out from the pitchstone, it is impossible to say, though nothing resembling them can be seen in the solid unaltered parts of the sill. Many of the nodular and spindle-shaped forms have diaphragms, which are not easily accounted for, but may be either the results of old cracks filled with exfiltration products, or veins in the pitchstone itself, and from the sides of which decomposition first set in.

On the surfaces of the undecomposed pillars of pitchstone, which break up into tabular masses, thin scale-like pieces may be found, and if these are examined as transparencies they will be found to be quite as good as prepared sections. Even with a pocket lens the "feathered" masses of starry microliths can easily be made out. These stars appear to be composed of minute microliths, arranged round others which stand up at right angles to them.

The accompanying illustration (Plate XI.) contains drawings of 37 different forms of microliths from the decomposed pitchstone, and which vary in length from ·2 mm. to 2· mm.

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No. XXVIII.—Corals and Coral Reefs. By J. G. Goodchild, F.G.S., Curator of the Geological Survey Collections in the Museum of Science and Art, Edinburgh.

[Read 8th December, 1898.]

[Abstract.]

The lecturer began by pointing out that the carbonate of lime, of which the hard parts of most corals consist, has been derived in the first instance from the decomposition of such eruptive rocks as basalt and dolerite. The lime is dissolved out of these rocks chiefly by the chemical action of the humus acids, which are formed by the action of bacteria upon the carbon compounds present in dead vegetable matter. One of the essential constituents of a coral is therefore drawn in the first place from the atmosphere, just as the other constituent, the lime, is derived from the heated interior of the globe. The carbonate of lime thus liberated is carried seawards from the land in the form of the soluble bicarbonate, which, at the zone where rivers enter the sea, is next converted into the sulphate of lime. In this form it is eventually diffused throughout the waters of the ocean, and from them it is continually being extracted by living organisms, by whose vital agencies it is then converted into the solid bicarbonate, of which the hard structures of marine organisms are usually built up.

The supply of sulphate of lime carried into the sea by rivers varies greatly according to local conditions, and within wide limits, but any extra demand upon that supply, such as must arise in those parts of the sea where great masses of coral reef are being built up, is sooner or later met by the supply carried thither by diffusion.

Hence the bicarbonate of lime poured into the sea by such a river as the Thames, for example, may eventually go to make good the defect caused by the drain upon the Atlantic Ocean by the corals living in the Gulf of Mexico, or even by those in the Pacific, just as the carbon extracted from the atmosphere by the sugar-cane of the West Indies may be eventually replaced by the carbonic acid liberated from the volcanoes of Iceland, or from others even still more distant.

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The mode of formation of a simple coral was then described, with its relation to the living animal. This was followed by a description of the structure of a coral reef, which was illustrated by many photographic views of typical reefs in one of the New Hebrides.

The concluding part of the lecture was principally devoted to some observations upon the question as to whether reefs are formed mainly in areas undergoing subsidence, as Darwin taught, or whether they occur chiefly in localities which are in process of upheaval, as was suggested by Semper, and since maintained by Sir John Murray. Mr. Goodchild thought the question was one chiefly of food supply, of pure sea-water, and, above all, of temperature. Reef-building corals cannot thrive in water which, even for a short time, ever falls below 68 deg. Fahr. Wherever, and to whatever depth, these suitable conditions prevail, there may coral reefs be formed, whether the land is stationary (which it probably never is for any length of time) or whether it is on the move, either upwards or downwards.

The paper concluded with a short account of the inhabitants of Aneityum, the particular island of the New Hebrides which had been described and illustrated.

A large series of fine photographs were thrown on the screen by the oxyhydrogen lantern, and a number of coloured diagrams and drawings of living Cœlentera were also exhibited.

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No. XXIX.—The Microscopical Examination of Rocks. By George R. Thompson, Lecturer on Geology in the Technical College.

[Read 12th January, 1899.

[Abstract.]

In the course of his remarks the writer pointed out the province of the microscope in the study of rocks, and that through its use a vast field, which was otherwise hid away from our unaided senses, was opened out for investigation. In many instances, of course, the component parts of rocks could be identified by the naked eye—granite, for example, and the coarser grits—but very little could be made of the finer igneous rocks, such as basalt, without the use of the lens. In the case of many of the fine Silurian greywackés, it was almost impossible to distinguish them from igneous rocks without microscopic aid, but when it was invoked the component particles were at once seen to be of a clastic nature.

The author then proceeded to examine the composition of the clastic and crystalline rocks, which were shown to have a definite structure or arrangement of their substances, as might be seen from the regular shape of the crystals where they have had free space to grow. The genesis of crystals as shown in glassy rocks was explained, as also the formation of crystallites, microliths, skeleton crystals, &c.

Mr. Thompson next pointed out how the different minerals could be recognised in microscopic sections by means of their physical and crystalline properties, such as shape, cleavage, colour, refracting index, and others. He ended his paper by giving a full and lucid description of the form of microscope best adapted for petrological work, with the production and use of polarised light, which was specially required in such work for determining the amount of double refraction, of the glassy matter, and the crystals of the different systems.

Sections of many of the rocks referred to in the course of the paper were thrown on the screen by means of the oxyhydrogen lantern, and numerous microscopes were placed on the table to show the effect of polarised light. A number of hand-specimens of the rocks were also exhibited.

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No. XXX.—A Bute Post-glacial Shell-bed. Notes on Excavations at the Rothesay Gasworks in 1896-1897. By John Ballantyne.

[Read 9th February, 1899.]

[Abstract.]

Bute has long been known for its post-glacial shell-beds. The first recorded was at Balnakailly Bay, Kyles of Bute, by Mr. James Smith, of Jordanhill, in 1831, where it occurs from a little above high-water mark to about half-tide level. Another was found near the centre of Rothesay in 1854 in an excavation of 19 feet for a tank at the Old Gasworks. Both deposits were described by Hugh Miller in an article entitled "The Chain of Causes." (See his "Sketchbook of Popular Geology," page 321.) The section of the latter is given as follows:—

1. Vegetable Mould or Soil, 1 foot 6 inches.
2. Ferruginous Gravel, (about) 7 feet.
3. Peat Moss, with Hazel Nuts, 1 foot 6 inches.
4. Fine Stratified Sea-sand, 9 feet.
5. Arenaceous Clay (shell-bed), so far as seen, 2 feet.

The surface was 20 feet above sea-level, so the shell-bed lay just 1 foot above it.

A third shell-deposit was found at Kilchattan Bay in 1847, where a deep clay-bed was being utilised for tile-making, though the shells do not seem to have been noticed till some years afterwards.

In 1877 a shell-bed was met with in the foundations for a sawpit and boiler at the Rothesay Sawmill, but no particulars were preserved.

Two excavations for gas tanks at the Rothesay New Gasworks, opening up a shelly clay, were made in 1896-1897, about 50 yards S. of the sawmills and 500 yards S. of the Old Gasworks deposit. The section here at 28 feet above sea-level was:—

1. Surface Soil and Sub-soil, 3 feet.
2. Sharp Sand, 5 feet.
3. Coarse Gravel, 2 feet.
4. Fine Muddy Clay (the shell-bed), 1 foot.
5. Fine Laminated Clay, 1 foot.
6. Boulder-clay (so far as seen), 10 feet.

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The shell-bed was here just 18 feet above sea-level. At one part of No. 3 many shells of *Mya truncata* were got, the first record of shells in this bed in Bute. The shell-bed (No. 4) was not continuous, lying on the N. side only of both excavations, which shows probably its limit on this side.

About 100 yards further S. of this a drain about 5 feet was dug in 1898, and the coarse gravel (No. 3) was met with, but there was no overlying sharp sand (No. 2).

The shell-bed at the Old Gasworks corresponds very nearly with those at Kilchattan Bay and at Balnakailly Bay.

A number of the travelled blocks found in the Boulder-clay at the New Gasworks were exhibited and described, their probable parent localities having been noted by Mr. C. T. Clough, F.G.S., of the Geological Survey.

Mr. Thomas Scott, F.L.S., kindly supplied the following:—

LIST OF SHELLS FOUND AT THE NEW GASWORKS.

Pleurotoma turricula, Mont.
Fusus antiquus, Linn.
Buccinum undatum, Linn.
Natica affinis, Gm.
,, *Grœnlandica*, Beck.
,, sp. (two fragments.)
Rissoa striata, Adams.
Littorina obtusata, Linn.
Trochus tumidus, Mont.
Tectura virginea, Müll.
Saxicava rugosa, Linn.
Mya truncata, Linn.
,, ,, (portion of syphon?)
Tellina calcaria, Chem.
Astarte compressa, Mont.
* ,, *sulcata*, Da Costa.
,, ,, var. *elliptica*, Brown.
Cyprina Islandica, Linn.
Cardium edule, Linn.
**Nucula nucleus*, ? (damaged.)
Mytilus modiolus, Linn.
Pecten Islandicus, Müll.
**Anomia ephippium*, Linn., var. *squamula*, Linn.
Balanus crenatus, Brug.
**Serpula triquetra*, Mart.
Echinus sp. (teeth, plates, and spines.)

* Not hitherto recorded for Bute.

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No. XXXI.—The Glacial Phenomena of Loch Ranza Glen, Arran. By Charles R. Cowie.

[Read 9th February, 1899.]

[Abstract.]

Some interesting glacial features of this locality, which do not seem to have been hitherto described, are here noticed.

Loch Ranza Glen is a narrow valley in the N.-W. of Arran, about 1½ miles long, nearly half being occupied by the tidal loch, which opens out into Kilbrannan Sound. The hill of Tor-Nead-an-Eoin, about 1100 feet high, divides the upper part into two glens, Glen Easan Biorach, running S. through the granite, and Glen Chalmadale, E. through the slate. A ridge of rock-debris with angular fragments and boulders, half a mile long and 30 to 40 feet high, and evidently a glacial moraine, lies on the S. side of the glen, behind the farms of Millhill and Milland. At each end it abuts on the hillside, containing a small lochan, the stream from which has breached it. The remains of another moraine, which formerly covered the bottom of the glen, are seen in Glen Easan Biorach, where on both sides they form terraces about 60 feet above the waterfall, and cease a quarter of a mile beyond. They consist almost entirely of granite boulders and debris, the underlying rock being clay-slate, and the steep slope above the burn is locally known as "the landslip." Another moraine stretches across the mouth of Glen Chalmadale from near the bridge to above Balarrie farmhouse, and covers a much greater surface than the last-mentioned one. A section is exposed in a gravel pit near the road, and another nearly opposite, where the burn has cut into it. At Kirn Point, on the N. shore, a group of large boulders extends into the loch, and reappears on the S. shore at Ferry Rock, where a well-defined ridge, about 12 feet high, is shown on the Admiralty chart. The fishing-bank off the bay, which stretches between Newton Point and Catacol Point, shows 12 to 14 fathoms water, while just outside it the depth becomes 22 to 30 fathoms. It is largely composed of boulders and shingle, mostly angular, with masses of clay-slate sometimes showing striations, so that it is evidently also a glacial moraine.

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When Kilbrannan Sound was filled with a mass of ice slowly forcing its way from the N.-W., as is shown by the gravel mounds behind the summit, and by the ice-markings in the glen, the ice-cap on Arran rose above the summit of Tor-Nead-an-Eoin. Crawling down from the centre of the island it eroded Glen Easan Biorach out of the granite, while another ice-stream from the E. cut Glen Chalmadale out of the slate. The two glaciers met at the head of Loch Ranza Glen, and the intense resulting pressure not only dug out the valley much deeper than the glens further back, but forced the ice over to the S. side, scarping the still-existing bow-shaped, almost vertical, crags. On the N. side they are not so steep, except at the corner opposite the junction, where they have been carved out by the ice which was forced round them. Their height is about 800 feet and they have certainly been higher.

Standing at the top of the talus below Tor-Nead-an-Eoin one can imagine the ice-masses here meeting, and crawling along with their rocky burdens from both glens, to join the larger stream in Kilbrannan Sound, and form the fishing-bank already mentioned. After a long period, as measured by the extent of the deposit on the bank, the pressure of the ice decreased, and the glacier retired to the narrower part of the loch, where a halt was again made. This resulted in the formation of the moraine between Kirn Point and Ferry Rock, and the deposition of many of the boulders. As it retreated backwards the lateral glaciers encroached on the valley, the most westerly at Wrinbeg causing the shoal opposite there, and a smaller one behind the Clacharine, both helping to form the ridge on which Loch Ranza Castle still stands. At this period the glacier which deposited the large moraine behind Milland came over the north slope of Meall Mohr, forming an ice-cascade over the crags, and eroding the hill above. Its thickness must have been from 200 to 300 yards, this being the distance of the moraine from the hillside. The shoulder of the hill was then laid bare, dividing the ice-stream into two, of which one portion came northwards, and the other went eastward down the side of Glen Easan Biorach. It gives us a fine example of the formation of the "horns" we hear of in Switzerland, and is itself known locally as "the horn." A

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stream of water issuing from the edge of the glacier at this point now contracted, the glacier causing it to produce another small moraine which forms a bifurcation at the eastern end.

The ridge in front of the large moraine is distinct, its inward side being very steep, with a deep hollow between it and the hillside, once filled with water overflowing to the west. Subsequently the overflow changed to the north or centre, where the stream cut the moraine right down to the ground level, leaving depth for only a shallow lochan behind. In Glen Easan Biorach the ice-stream was hemmed in by the narrow gorge, where it formed the moraine already described, and the resulting stream of water has cut through the rocks to the depth of from 60 to 80 feet. This will give some idea of the vast period of time since the retiral of the glaciers into the river valleys. Valuable chronological data might be got from the erosion of the rock below the glaciers, and beside "the horn" on the side of Meall Mohr, as well as from the perfect moraine behind Millhill and Milland; but these must be left for future work.

The ice has disappeared from the glens; paleolithic and neolithic men have gone, leaving the old fort on the hill; the glens have seen the invading Dane and Norseman, and the Bruce has visited the peaceful convent in the vale, and built the castle on the margin of the loch. Of the fort and the convent only a few stones remain to mark their sites, and even the castle is a crumbling ruin, but the evidences of the giant forces of nature still exist to tell us of the methods by which she has asserted her irresistible will.

The paper was illustrated by maps, diagrams, and a series of photographs thrown on the screen by the oxyhydrogen lantern.

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No. XXXII.—The Silurian Volcanic Rocks of the Southern Uplands of Scotland. By John Horne, F.G.S., of the Geological Survey.

[Read 23rd February, 1899.]

[Abstract.]

Reference was made at the outset to the great development of volcanic rocks of Arenig age in the Southern Uplands, where they are brought to the surface along the crests of anticlinal folds. The largest area of these rocks now exposed at the surface occurs in the neighbourhood of Ballantrae, Ayrshire, where they consist of a succession of diabase and diabase-porphyrite lavas, tuffs and agglomerates. The age of these volcanic materials is clearly defined by fossiliferous flinty mudstones interstratified with the lavas, and by black graptolitic mudstones in the tuffs and agglomerates near the top. The organisms obtained from these deposits comprise graptolites of Middle Arenig age, and hingeless brachiopods, together with a phyllopod crustacean. The lavas, tuffs and agglomerates of Arenig age, are overlain in Ayrshire and throughout the Uplands by an important zone of radiolarian chert belonging partly to Arenig, and partly to Lower Llandeilo time.

Thereafter the various intrusive igneous rocks associated with the volcanic series of Ballantrae were indicated, which include masses of serpentine, gabbro, epidiorite, dolerite and granite: their relations to each other in the field being in many places obscure. It was shown that towards the close of Llandeilo time the volcanic and plutonic rocks of the Ballantrae region, together with the overlying sediments, were elevated and exposed to denudation, the materials of the Kirkland and Benan conglomerates at the base of the Girvan series having been derived from these older rocks. Thereafter attention was directed to the numerous inliers of Arenig volcanic rocks exposed in anticlinal folds, in the northern belt of the Uplands stretching from Sanquhar by the Leadhills and Abington to Leadburn, north of Eddleston, which comprise lavas, tuffs, and agglomerates. Reference was further made to the occurrence of thin lenticular bands of diabase-lava and andesitic tuff at isolated localities in the Lower

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Caradoc rocks and to the closing phase of volcanic activity in Upper Caradoc time. The latter is of special interest as the lavas consist of soda-felsites and perlitic felsites with calcareous tuffs in which fossils are embedded, at Wrae, Glencotho, Hamilton Hill, and Winkston.

The lecture was illustrated by a large series of photographic slides thrown on the screen by the oxyhydrogen lantern.

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No. XXXIII.—Extinct Birds. By R. H. Traquair, M.D., LL.D., F.R.S., Keeper of the Natural History Collections in the Museum of Science and Art, Edinburgh.

[Read 31st March, 1899.]

[Abstract.]

The lecturer observed that comparative anatomy showed that birds were more nearly allied to reptiles than to mammals, however striking the external differences between them might be. Hence the late Professor Huxley had included birds and reptiles in one common group—the Sauropsida. Evolutionists believed that birds had originated from reptiles, though it was not known from what order of reptiles they were descended. The resemblances between birds and the Pterodactyles, or winged reptiles of the Jurassic epoch, were merely adaptive, but some of the likewise extinct order of Dinosauria had certainly bird-like osteological peculiarities.

It was, however, interesting to know that the oldest known fossil bird—the Archæopteryx of the Upper Jurassic—was more reptile-like than any later bird, inasmuch as it had teeth in its jaws, a less specialised anterior extremity, and the caudal part of the vertebral column was elongated and tapering. The Archæopteryx formed one of the three great divisions into which birds were classed by Huxley—namely, the Saururæ, or lizard-tailed; the other two being the Ratitæ, or ostrich-like birds, and the Carinatæ, which included the overwhelming majority of living species.

The Ratitæ comprised the Ostrich, the Emu, &c., running birds with degenerate wings, and consequently incapable of flight. Remains referred to Ratitæ have been found in Tertiary strata, but the most complete were those from the more recent accumulations, such as the Æpiornis, or Giant Bird, of Madagascar, eggs of which have been found measuring 14 inches in length; and the huge Moas of New Zealand, some of which (*Dinornis maxima*) attained a height of 12 feet. The carinate birds had their breast-bone keeled, to afford attachment to the powerful muscles of flight, though some were flightless, and others have even lost the keel on their breast-bone. Their remains first appeared in the Cretaceous rocks, and it was also

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interesting to note that among these ancient carinates, two forms—Hesperornis and Ichthyornis—had teeth in the jaws, like Archæopteryx. Fragmentary remains of extinct species of the principal types of carinate birds were found in strata of Tertiary age, so that these must already have been differentiated before the end of the Cretaceous epoch.

Many birds had, however, become extinct in comparatively recent times, of which the most interesting were certain large flightless birds, which lived upon islands uninhabited by man, or by large or predaceous mammals, and whose wings, not being required for the protection of their lives by flight, evidently ceased in the course of long ages to be functional. They were quite adapted to their surroundings as they were, but on the arrival of man with his domestic animals, they succumbed and disappeared. Such were the Dodo of Mauritius and the Solitaire of Rodriguez. Some birds had lost their power of flight, not by disusing their wings, but by using them for another purpose—namely, as paddles for swimming, as in the case of the Penguins and the Great Auk. The latter was now extinct, the last having been seen in 1844. Various birds living or breeding on islands have also become extinct in modern times, such as the Labrador Duck, the New Zealand Quail, the Hackled Pigeon of Mauritius, &c. In Great Britain some birds, as the Crane, Spoonbill, and Great Bustard, were now extinct as native breeding species, though stragglers might sometimes be found. Other British birds were threatened with extinction, such as the Great Skua, or "Bonxie," and the Osprey.

In conclusion the lecturer urged the importance of the protection of our native birds which are in danger of extinction from one cause or another. Such Acts of Parliament as have already been passed for the purpose and were now in operation were having a wholesome effect in diminishing the destruction of our feathered friends, but it was to be hoped that still more would be done towards checking the wanton destruction of birds' nests that went on every season, and of the wanton shooting of sea-birds and water-birds on our coasts. There might be some species, such as the Rook, the Woodpigeon, and the Sparrow, whose undue multiplication it might be necessary to keep in check, but not to the verge of extinction, as in many ways these birds served a most useful end.

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No. XXXIV.—Moraines and Deltas. By Matthew Blair, *V.P.*

[Read 4th May, 1899.]

[Abstract.]

The important discoveries amongst the Ayrshire Drift-beds which Mr. John Smith recently placed before the Society, have naturally attracted a considerable amount of fresh attention to the Surface Geology of Western Scotland, the study of which seemed to be in danger of falling into abeyance, or of being passed by as of little consequence.

The author defined his object, therefore, in giving the present paper as an attempt to describe the great accumulations of detrital material which lie widely scattered over the lower levels of our country, as their varying modes of origin do not appear to be clearly understood, or, as in some recent text-books, to be altogether mis-stated. With this object in view he proceeded to define the clear distinctions which he believed to exist between the three principal varieties of these accumulations—in the shape of moraines, deltas, and raised beaches. He gave the results of his experiences in the examination of existing glaciers in Switzerland and Norway, and described the formation and appearances of their moraines, whether medial, terminal, or lateral, as exemplified by some of the more typical examples he had seen.

He then referred to the mounds or terraces which had a delta origin—that which resulted from the deposition of the debris of denuded rock formations, in water, whether salt or fresh, through the action of streams—and pointed out that the presence of such deltas above the water line always indicated a considerable alteration of levels.

When the accumulations of drift matter were formed by the action of the sea, as ancient sea-beaches, they invariably bore evidences of their marine origin in their shape and position, which differentiated them from moraines and deltas.

A number of the more characteristic mounds and beds of detritus on our coast lines and on the inland lower levels, which had been mentioned in the course of the paper, were described in detail by the author, and were also illustrated by a series of fine photographs thrown on the screen by the oxyhydrogen lantern.

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No. XXXV.—Lord Dundonald, 9th Earl, the Discoverer of Coal-gas as an Illuminant. By Robert Craig, Honorary Member.

[Read 25th May, 1899.]

[Abstract.]

When Mr. John Smith exhibited, in January last, "specimens of the substance from which William Murdock first made gas," my intention was to have attended the meeting, and to have pointed out that he (Murdock) was not the discoverer of coal-gas but that Lord Dundonald was. Being, however, prevented from coming that evening through illness, I now send this note on the subject.

I have no wish or intention of detracting from the merits of William Murdock, who if not a man of genius was at least a man of talent, and one who knew how to use both his head and his hands. Of late years it has become the fashion to put him forward as the discoverer of coal-gas, and also as the assistant of James Watt in perfecting the steam-engine, but these are both pure fictions.

The real discoverer of coal-gas as a product from coal, and its first application as a powerful illuminant, was Lord Archibald Cochrane, 9th Earl of Dundonald, a man of transcendent genius. First joining the navy, he then went into the army, but not finding either profession to his mind he settled down to devote his life to science, principally chemistry, at a place, I believe, called Annsfield, near Glasgow.

Amongst his other discoveries was the production of gas-tar —as it is now called—from coal. When working at this at Culross Abbey, in Fife, he observed an easily ignited blue vapour being given off, and fixing an old gun barrel to one of his condensers he lighted the escaping gas at the outer end. This was the first introduction of gas as a curious lighting experiment, but he does not seem to have tried to bring it into practical use, as he was intently pushing his newly discovered coal-tar as a preservative of the bottoms of wooden ships; at that period usually destroyed in about three years by a marine boring worm. To prevent its ravages the timbers were thickly studded with flat-headed nails, but this was done only in the case of the larger ships.

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To manufacture the tar he took out a patent and started works at Muirkirk, Ayrshire, where he lighted a shed with gas conveyed through an old gun barrel from a condenser, as he had previously done at Culross. Unfortunately this work was not long in operation, when some one invented copper sheathing for covering ship's bottoms, and this quite superseded Lord Dundonald's patent tar.

Murdock, who had been employed in the erection of the tar works at Muirkirk, or in some other capacity about them, saw the use the gas was put to, and when he afterwards got into the Soho Works at Birmingham, under Boulton and Watt, he put his previously acquired knowledge to practical account, by first lighting the place he worked in with gas which he made, and then, with the assistance of Boulton and Watt, he erected the first gaswork, from which the whole of the Soho Works were lighted, and which was very much on the lines of those of to-day.

Lord Dundonald was using gas as an illuminant as early as 1782, at Culross Abbey, and on his way to London about that time he called on Watt, and explained his gas discovery. One writer says that perhaps Murdock may have afterwards got his knowledge of gas from Watt, but I believe that, as already stated, Murdock learnt the use of gas for himself at the Muirkirk tarworks.

In any case, as the inventor of the gaswork, who brought gas into practical use as an illuminant, Murdock's fame is sure, though probably Watt's knowledge as a chemist must have assisted him—for instance, in the purification of gas by passing it through lime and water.

Lord Dundonald, the 9th Earl, the real discoverer of coal-gas, was a chemist of profound knowledge, though not a man of business tact, and hence he failed to benefit himself and his family by many of his inventions and discoveries which were far in advance of his time. This is perhaps not the place, nor the opportunity, to say more than that I believe his discoveries deserve an exhaustive paper beyond those of any neglected genius whom I at present remember.

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PROCEEDINGS FOR SESSION 1897-1898.

(40TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 14TH OCTOBER, 1897.

Mr. ROBERT DUNLOP, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. J. B. Murdoch) exhibited specimens of Pebbles of various rocks from the conglomerate of Old Red Sandstone age, occurring at Dunottar Castle, Kincardineshire. They all had a bright surface polish of oxide of iron, the cause of which was not apparent. An interesting discussion was taken part in by Dr. John Young, F.G.S., Messrs. P. Macnair, James Neilson, *V.P.*, J. S. M'Lennan, and the Chairman.

Mr. JAMES NEILSON, *V.P.*, exhibited several specimens of Finely Laminated Clay from Kelvinside, showing a beautifully banded formation. From blocks cut from this bed he had constructed a series of models of stratified rock-sections, which he also showed.

Mr. WILLIAM ARMOUR, C.E., read a paper upon the Society's excursion, taken in June, 1897, to Murroch Glen, and Auchenreoch Glen, Dumbartonshire, and gave an account of the various geological phenomena met with. Amongst other minerals some fine specimens of fibrous gypsum were found, also of celestite, one of the barite group, not previously recorded from the West of Scotland.

Mr. JAMES NEILSON, *V.P.*, read some additional notes on the excursion, and exhibited a number of specimens of the rocks and minerals.

Mr. WILLIAM SINCLAIR read an account of an excursion to Finnich Glen, one of the best Scottish examples of the rock-gorge known in North America as a "cañon."

Remarks were made on these papers by Dr. John Young, F.G.S., Messrs. J. Stark, J. Sommerville, and others.

On behalf of Mr. John Smith the HON. SECRETARY read a paper entitled "Notes on some Dry River Channels in Ayrshire and Lanarkshire."

The author said that since his paper on "Dry River Channels near Muirkirk" (*Transactions*, vol. x., part 2, page 331), he had observed four other dry channels as follows :—

1. On the S. side of Gogo Burn, Largs, Ayrshire, and about 150 feet above sea-level. This may have been the channel on the S. side of an island in the stream which resulted in the lowering of the channel about 100 feet, the denudation being cut entirely through drift.

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2. Near the head-waters of the Avon, on the Lanarkshire side, and about half a mile above the moraine, there is a considerable channel mostly dry and nearly parallel to that of the Avon, from which it is separated by a long drum of drift. In its wanderings the Avon has tapped this stream by a steep short cut which leaves the old channel of the burn mostly dry.

3. Between Carcow Burn, New Cumnock, Ayrshire, and Penclose House there is a deep dry gutter like a railway cutting, which branches off from the right bank of the glen about 40 feet above the level of the present stream, and 900 feet above sea-level. Though very artificial-looking, it is probably quite natural. Just above the slope of the Carcow Glen there is a small roundish knoll, which so far as could be found has no name, an unusual circumstance. This channel may have been excavated by the Lochingirroch burn when its mouth was closed by the Glen Afton glacier.

4. Near South Garphar, Ballantrae, Ayrshire, and N. of the farm steading, an old channel has an average width of about 16 paces at the bottom, and is from 16 to 20 feet deep. Rock is seen at one part on the S. side, but elsewhere it seems to be entirely cut out of drift. After about 300 paces it is joined by a small ditch, evidently a continuation of the channel, which falls into the Bellman burn. This channel was probably the course of the Tig Water during the latter part of the glacial period, when the glacier of the Stinchar Valley choked up its mouth and compelled the Tig to flow over the shoulder of the high ground at Auchenflower and South Garphar. At its highest part it is about 300 feet above sea-level.

In the following discussion Dr. YOUNG pointed out that these old river channels were recent compared with others in the neighbourhood of Glasgow which were known to have been cut through some of the coal and sandstone strata, but afterwards filled in and covered up by subsequent deposition of stratified rocks or by Boulder-clay.

On behalf of Dr. Forster-Heddle, of St. Andrews, who was unable to be present through illness, the HON. SECRETARY read a paper on "The Minerals of the Islands of Faröe," the interesting little Danish archipelago which lies about 170 miles N.W. of Shetland.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH NOVEMBER, 1897.

ANNUAL GENERAL BUSINESS MEETING.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. J. B. Murdoch) read as follows :—

REPORT OF THE COUNCIL FOR 1896-1897.

At the commencement of a new session it has, for many years, been the practice of the Council to submit a Report giving a summary of the work

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and occurrences of the past year, and noting any special features which may call for remark.

The MEMBERSHIP has remained at about its recent average, the accessions nearly balancing the losses by death and withdrawal, but the Council think that the total number can hardly be thought a fit one for the membership of a society in a city so largely interested, directly and indirectly, in the results of mining and geological work. They would, therefore, again urge the members to enlist some of their friends and acquaintances as new blood for the Society.

The FINANCES are on the whole in a favourable condition, and they will be reported on by your Hon. Treasurer, Mr. John Wight, C.A.

The LIBRARY work has been carried on with success by your Hon. Librarian, Mr. James S. M'Lennan, who will submit his Report for the year.

The MEETINGS were nine in all, and were attended by much the usual average of members. An extra meeting was held on the 22nd of April, when an admirable paper on "Desert Conditions in Britain" was given by Mr. Goodchild, F.G.S. Invitations to attend this meeting were issued to members of other scientific societies in Glasgow, and were largely taken advantage of. [See *Trans.*, vol. xi., part 1, page 71.]

The PAPERS read during the session were of considerable value and importance. A number of them have already been issued, either *in extenso* or in abstract, in part 2 of vol. x. of the *Transactions*, or will appear in the following one.

The SPECIMENS shown at the various meetings, whether accompanying papers or as separate exhibits, were numerous, and of considerable interest and value.

The TRANSACTIONS.—A new part (vol. xi., part 1) is now in progress and will be ready for issue early next year.

The important discoveries of Mr. John Smith in the Ayrshire Drift or Glacial Beds were embodied at great length in his paper read in April, 1897, and the printing committee resolved to print it in full, with illustrative diagrams. As the Council approved of this the work was at once commenced, and is now well in hand. [See *Trans.*, vol. xi., Supplement.]

The EXCURSIONS of the season were ten in number, most of them being well attended—some of them largely so. As in last year, they were extended over several of the autumn months, which seemingly suited many of the members. This year some of the conductors brought up notes on the excursions at the ensuing meetings, a practice which will, the Council hopes, become general, so that interesting local geological features may thus be preserved. [For a List of the Excursions see page 315.]

The CORRESPONDING SOCIETIES' COMMITTEE OF THE BRITISH ASSOCIATION As the meeting of the British Association took place in Canada this year the Society was not represented by any delegate, but it is hoped that both its Boulder Committee and Photographic Committee will have some accumulations of material to submit to the Corresponding Societies' Committee at its next meeting.

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The Loss of Members.—During the year various well known members have gone from amongst us. The Society, as well as the scientific world generally, suffered irreparable loss in the death of Dr. David Robertson, F.L.S., F.G.S. At the December meeting of 1896 Mr. James Neilson (Milnbank) contributed a notice of the deceased gentleman. Amongst the others may be noted Mr. Adam Knox, a member for many years, and at various times a member of Council; Mr. William Dow, for long a most regular attender of meetings and excursions; and Mr. Edward Carrick, one of the younger members, who went out to South Africa some years ago, receiving the appointment of mining commissioner at Umtale, but which post he did not live long to fill, as he was lately carried off by fever.

The Hon. Treasurer (Mr. John Wight, C.A.) read the Financial Statement. [For an Abstract of Accounts see page 319.]

The Hon. Librarian (Mr. J. S. M'Lennan) read his Report upon the Library.

These Reports all showed a prosperous state of the Society's affairs.

A cordial vote of thanks to the standing officials for their labours in the Society's behalf was then proposed and unanimously responded to.

The Vacancies occurring in the Council at this time were filled up as follows:—As Vice-President, Mr. John Renwick; as Members of Council, Messrs. Matthew Blair, Peter Macnair, James Neilson (Milnbank), and James Neilson (Port Dundas); all for a term of three years.

Mr. John R. M'Farlane and Mr. G. R. Thompson were elected Auditors for the current year.

Mr. Robert Dunlop, *V.P.*, proposed the following motion:—"That the Council be empowered to make arrangements for the Disposal of the Society's Collection of Rocks, Minerals, and Fossils," which was seconded by Mr. M. Blair, *V.P.*, and unanimously agreed to. It was remitted to the Council to form a small committee to endeavour to arrange with the Corporation of Glasgow in the terms of the motion.

Mr. Thomas Gilfillan, Photographer, 28 Abbotsford Place, and Mr. Henry Thomson, Metal-broker, 10 Princes Square, Strathbungo, were elected Ordinary Members.

Mr. James Neilson (Milnbank) exhibited (1) specimens of Fossiliferous Ironstones from Arran, on which he made some remarks.

Dr. Young stated that similar ironstones which occurred at Campsie and at Dalry contained almost identical minute spiral shells.

Mr. Neilson exhibited (2) an Early Paper on Arran Geology—"The Geological Relations of the Secondary Strata in the Island of Arran," by Messrs. Sedgwick & Murchison, originally printed in the *Transactions of the Geological Society* for 1828, but issued as a separate pamphlet, and containing a fine coloured section of the S.-E. shore-line of the Island.

Mr. Neilson exhibited (3) "The Mineralogy of Arran," by the Rev. James Headrick, an early work on the Island, which was published in 1807. The author was a Wernerian, and records in this volume the discovery of fossils in the basalt of the Shiant Isles.

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The Hon. Secretary (Mr. J. B. Murdoch) read, on behalf of Mr. Robert Craig, Beith, a paper—"Notes Retrospective on the Closing of the Quarries of Greenhill, Kilmaurs, Ayrshire." [See page 192.]

Remarks upon the paper were made by Dr. John Young, F.G.S., Mr. J. S. M'Lennan, and other members, who had visited these well-known quarries before their final disuse.

Mr. G. M. Pratt (Assist. Hon. Secretary) called the attention of the members to the recent interesting discovery of *Cephalaspis* and other fossil fishes in Old Red Sandstone near Oban, and which up to the present find was supposed to be without organic remains.

Society's Rooms, 207 Bath Street, 9th December, 1897.

Mr. John Renwick, *Vice-President*, in the Chair.

Mr. Samuel Fingland, 15 Broomhill Avenue, and Mr. Francis D. Weir, M.E., 15 Alexander Street, were elected Ordinary Members.

Mr. James Stark exhibited the following specimens: (1) White Limestone, perforated by boring molluscs and sponges, from Marseilles; (2) a thin mineral band in the argillaceous shale of the Calciferous Sandstone series of Great Cumbrae, resembling gypsum, but probably arragonite; (3) a Geological Map of England and Wales, by William Smith, "the father of English Geology," published in 1824.

Remarks on these were made by Dr. John Young, F.G.S., Messrs. James Neilson (Milnbank), J. Sommerville, G. R. Thompson, J. S. M'Lennan, and other members.

Mr. Peter M'Nair read a paper "On the Giffnock Sandstones and the Conditions under which they were accumulated." [See page 199.] An animated discussion followed, and was taken part in by Dr. John Young, F.G.S., Mr. J. Neilson (Milnbank), and other members.

Society's Rooms, 207 Bath Street, 13th January, 1898.

Mr. Robert Dunlop, *Vice-President*, in the Chair.

A motion that £10 of the Society's Funds should be devoted to Library purposes during the current session was proposed by Mr. James Steel, seconded by Mr. J. Sommerville, and unanimously agreed to.

Mr. Andrew M. Burdon, Teacher, Oakbank, Bellshill; Mr. David H. Fotheringham, Surgeon, 41 Garthland Drive, Dennistoun; and Mr. John M'Kellar, Property Agent, 25 Kelvinside Terrace, South, were elected Ordinary Members.

Mr. James Campbell, Clerk, 5 Leslie Street, Pollokshields; Mr. William F. Clark, Clerk, 167 Crown Street; Mr. James Paterson Cree, Power-loom Tenter, Westfield Place, Rutherglen; Mr. Alex. Mackay, M.E., 123 St. Vincent Street; Mr. David Nimmo, jun., 17 Duke

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Street, Hamilton; and Mr. William Sommerville, Clerk, 2 Miller Terrace, Rutherglen, were elected Associate Members.

Mr. JOSEPH SOMMERVILLE exhibited, on behalf of Mr. James Wilson, the right half of the Lower Jaw of *Bos primigenius*, an extinct British ox, from the Paisley clay-beds, also a Rib-bone, probably of the same species.

Dr. JOHN YOUNG, F.G.S., made some remarks upon the occurrence of a number of Skulls and Bones of *Bos primigenius* in the Clyde area, and stated that several of them were preserved in the Hunterian Museum.

R. H. TRAQUAIR, M.D., LL.D., F.R.S., Keeper of the Natural History Collections in the Museum of Science and Art, Edinburgh, read a short communication upon *Palæospondylus*, a curious minute fossil fish as yet found only in a single locality in Caithness, and seemingly allied to the modern Lampreys. In illustration of his remarks Dr. Traquair also exhibited a fine series of specimens of this interesting fish.

Mr. R. W. DRON, C.E. and M.E., read a paper on "Goldmining in the Sierra Nevada, California." [For an Abstract see page 265.] The paper was largely illustrated by diagrams, and by specimens of the rocks.

A following discussion was taken part in by Dr. John Young, F.G.S., Mr. G. R. Thompson, and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 27TH JANUARY, 1898.

SPECIAL MEETING.

Mr. ROBERT DUNLOP, *Vice-President*, in the Chair.

Mr. GOODCHILD, F.G.S., Curator of the Geological Survey Collections of Rocks and Minerals in the Museum of Science and Art, Edinburgh, delivered a lecture on "Geological Time." [For an Abstract see page 267.] The paper was illustrated by a large series of slides shown by the oxyhydrogen lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH FEBRUARY, 1898.

Mr. JOHN RENWICK, *Vice-President*, in the Chair.

Mr. John Anderson, Colliery Manager, Elenslee, Bothwell; Mr. James Bain, Colliery Manager, 4 Gardenside Terrace, Uddingston; Mr. James Bell, Architect, Garvald, Cameron Street, Motherwell; Mr. Alexander Munro, Mineral Boring Prospector, 1 Colebrooke Place, Hillhead; Mr. John Scott, Quarrymaster, Motherwell; and Mr. W. S. Stewart, F.R.A.S., Levern, Barrhead, were elected Ordinary Members.

Dr. JOHN YOUNG, F.G.S., exhibited specimens of Flaggy Sandstones of the Carboniferous Limestone series, containing numerous perforations of the vertical burrows of soft-bodied Annelids, allied to the genus *Arenicola*, the common lob-worm of our present seas. He pointed out that the ringed worms, *Annelida*, have had a long geological history, as they swarmed in

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the sandy deposits of the Cambrian seas as well as in some of the marine deposits of the later formations up to recent times. As stated in the text-books they were all soft-bodied animals, and so we do not find their actual remains in the fossil state, but we possess abundant traces of their existence by the presence of the vertical burrows they have left in the strata. Those burrows found in the flaggy sandstones of the Scottish coal-fields afford evidence of the existence of at least 3 or 4 species, which are distinguished by the different shapes of the burrows. One form that crowds the surface of the slabs of some of the flaggy sandstones at the Giffnock quarries (Burnfield) shows the burrows descending into the rock vertically to the depth of from 2 to 4 inches. Another interesting form, in South Mine Quarry, Bathgate, shows the burrows to be arranged in pairs, with the tubes uniting at the bottom, or in other words each pair having a form like the capital letter U. It is supposed that in this species the one opening served for entrance and the other for exit. Other forms have conical-shaped openings at the surface, and one from the Ayrshire coal-field, recently discovered by Mr. John Smith, shows double U-shaped tubes, and of a larger size than any previously found in Western Scottish strata.

Mr. JOHN SMITH exhibited specimens of a curious set of small bodies found in a fossiliferous shale exposed on the railway from Giffen to Kilbirnie in Ayrshire. These bodies are still undetermined, but belonged, he believed, to one of the Carboniferous Nudibranchs, and for which he therefore proposed the provisional name of *Archæodoris carbonarius.*

Mr. JOHN SMITH read a paper on "Holes filled with soft reddish shale in the *Spirorbis* Limestone of Ballochmyle, Ayrshire." These holes had evidently been formed in the limestone before the overlying bed, also limestone, had been laid down, but as no remains of the animals which had made them have been preserved it is impossible to say what they were. Possibly they may have been Annelids.

A series of rock specimens were shown in illustration of the paper.

Mr. SMITH also read a short paper on "A Purple Rock with Glittering Spots" ("Skinkle Rock") found in the same cliff as the *Spirorbis* Limestone. These spots appear to be aggregations of crystallised calcite, probably ophi-calcite. They have not displaced the sand-grains of the matrix, but are mixed with them, and as the facets of each crystal all lie in the same plane with one another, so at a given angle they all reflect the light rays.

Specimens of the "Skinkle Rock" were exhibited.

The HON. SECRETARY (Mr. J. B. Murdoch) read "A Notice of the Life and Geological Work of the late Dugald Bell, F.G.S.," one of the original members of the Society, for some years its Honorary Secretary, and up till a late period in 1896 a large contributor to its Proceedings, whose lamented death occurred on 15th January, 1878.

At its close some feeling remarks on the loss sustained by the Society, and by individual members who had been intimate friends of the deceased

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gentleman, were made by Mr. William Jolly, F.G.S.; Dr. John Young, F.G.S.; Mr. William Armour, Mr. James Neilson (Milnbank), Mr. Joseph Sommerville, and Mr. J. S. M'Lennan.

SOCIETY'S ROOMS, 207 BATH STREET, 24TH FEBRUARY, 1898.

SPECIAL MEETING.

Mr. ROBERT DUNLOP, *Vice-President*, in the Chair.

R. H. TRAQUAIR, M.D., LL.D., F.R.S., Keeper of the Natural History Collections in the Museum of Science and Art, Edinburgh, gave a lecture on "The Bearing of Fossil Ichthyology on the Doctrine of Evolution." [For an Abstract see page 269.]

The paper was illustrated by a large series of slides shown by the oxyhydrogen lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH MARCH, 1898.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

Dr. A. Freeland Fergus, 203 Bath Street, and Mr. Alexander M'Gavin, 23 Melrose Gardens, were elected Ordinary Members. Miss Marianne S. Beard, 14 Ruthven Street, Kelvinside, and Mr. James Rodgers were elected Associate Members.

Mr. JOHN MACKIE, M.E., read a paper entitled "Notes on Volcanic Ash interbedded with Loose Sand as exposed at Crofthead, Neilston." In the course of his remarks Mr. Mackie stated that his observation on these beds had been made during the levelling of a sloping piece of ground for the extension of Crofthead Thread Works, at Neilston, and situated at the N.E. end of the Cowden Valley. The rocks exposed here, and in the valley, are mostly indurated volcanic ash, but at the S.-W. end they come in contact with the Carboniferous strata, which stretch from this point into Ayrshire, while at the opposite (N.E.) end they meet the Carboniferous rocks which extend into Lanarkshire. He proceeded to give a description of the various surface beds in the 6-acre area covered by the Crofthead Works which consist of sand and gravel over Boulder-clay, and that rests on volcanic ash. At the beginning of the new excavation the material consisted mostly of sand and gravel, and Boulder-clay and boulders, but as the cutting went further into the bank, where it ultimately reached a depth of 30 feet, an almost solid bed of volcanic ash was met with. This ash was beautifully stratified on the top, and contained interbedded layers of loose sand, as was first pointed out by Mr. John Smith. After a full description of these various deposits, the author described the boulders which had been met with during the progress of the work—many finely striated—and including several of granite and limestone, those of the former being, however, very rare. Mr. Mackie then spoke of the very

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interesting section of inter-glacial beds discovered in the Cowden Valley during the formation of the Kilmarnock Joint Railway, and which lie not far from the area previously described. These became the source of a hot and strong controversy amongst members of the Society at that date, numerous papers being afterwards read and discussed at subsequent meetings.

The paper was illustrated by a number of diagrams, and specimens of the rocks. At its close remarks were made by Dr. John Young, F.G.S., Mr. Peter Macnair, Mr. Goodchild, F.G.S., Mr. John Smith, and Mr. James Neilson (Milnbank).

Mr. Goodchild, F.G.S., Curator of the Geological Survey Collections of Rocks and Minerals in the Museum of Science and Art, Edinburgh, read "A Notice of the Life and Work of the late Dr. Forster-Heddle, F.R.S.E., Emeritus Professor of Chemistry in the University of St. Andrews, and Honorary Member of the Society." After giving many interesting details of the life and work of the deceased gentleman, the author sought to account for the bias and tendency of his mind as being derived from the environments of his ancestors amid the grandeur, gloom, and mystery of their Norwegian homes, and from their deeds of daring, and determination in retaining and defending their hard-won possessions. He thought that heredity was a large factor in developing a character like that of Dr. Heddle, brave, self-reliant, hardy, and ambitious of great things, as well as honest and patriotic.

Remarks in remembrance of Dr. Heddle and on the loss sustained by the Society in consequence of his death were made by several of the members.

Society's Rooms, 207 Bath Street, 14th April, 1898.

Mr. Robert Dunlop, *Vice-President*, in the Chair.

The Hon. Secretary (Mr. Murdoch) referred to the recent death of a well-known and active member of the Society, Mr. John Kirsop, and who was for many years a constant attendant at its meetings and excursions.

Mr. John Smith exhibited a number of specimens as follows:—

1. *Spirorbis helicteris*, from the Upper Carboniferous Shale, Dreghorn, Ayrshire. It occurs in considerable masses in a band, and on nodules, of clay-ironstone. Flat surfaces of attachment are seen on some of the *Spirorbis*, and from their great numbers, they were probably attached to one another.

2. Freshwater Limestone from the same exposure. This limestone is very much banded, most of it consisting of thin leafy layers, the surfaces of which are often curiously ridged.

3 *Lingula*, from the Upper Carboniferous strata of Ayrshire. In the sinking of the Drumley Pit, near Annbank Station, at about 145 fathoms, a dark shale contained a number of *Lingula* like small *L. mytaloides*. This shale seemed to be much the same as the *Lingula* shales in the

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Dalry lower ironstone series. The only accompanying fossils were a few small fish scales. In 1870 Mr. Smith found *Lingula* in the Upper Carboniferous Rocks of Auchinleck parish. That the genus is generally absent from these strata was good negative evidence that they were of freshwater origin.

Remarks upon several of the specimens were made by Dr. John Young, F.G.S.

Mr. JOHN SMITH read a paper on "The China-clay Mine and the Water-of-Ayr Hone-stone Bed at Troon, Ayrshire." [See page 238.]

The paper was illustrated by a number of specimens, and remarks were made by Dr. John Young, F.G.S., and Mr. Joseph Sommerville.

Mr. JOHN SMITH read a paper on "The Barite Veins of South-West Scotland." [See page 232.]

The paper was illustrated by specimens. Remarks were made by various members.

Mr. PETER MACNAIR read a paper entitled "Additional Proofs and illustrations of the Evidences adduced in my former paper on the Giffnock Sandstones. [See page 199.]

The paper was illustrated by sectional diagrams, by specimens, and by lantern slides from photographs taken by Mr. S. Fingland.

Mr. S. FINGLAND exhibited a number of Photographs of Fossil Plants from the Sanquhar coal-field, which were thrown on the screen by the oxyhydrogen lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 5TH MAY, 1898.

Mr. JOHN RENWICK, *Vice-President*, in the Chair.

Reference was made by the CHAIRMAN to the recent death of Sir James Bain, who had been a Life Member of the Society since 1875.

A discussion adjourned from last meeting on Mr. Macnair's "Giffnock Sandstones" paper was then taken up, remarks being made by Dr. John Young, F.G.S., Mr. Joseph Sommerville, and the author. From differences of opinion on various points, an afternoon excursion to Giffnock was arranged for the 11th May.

Mr. JOHN SMITH read several short papers as follows:—

1. On a Flexed Structure in the Pitchstone of Corriegills, Arran.
2. On a drawn-out Spherulitic (?) Structure in a Trap Dyke in Great Cumbrae.
3. On a Globular Structure in a Trap near Neilston.
4. On Volcanic Ash with Gravel- and Sand-beds near Neilston.

In this paper Mr. Smith stated that in a cutting of the new L. & A. Railway, about half-a-mile S.-W. of Neilston there is 12 feet of purple ash, and in the ash a band of gravel with pebbles up to 4 inches in diameter. Lower in the ash-bed are three lenticular bands of dirty grey sand. This bed is at a much higher level and quite different in character

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from the Crofthead Mills bed [see *Trans.*, vol. xi., page 299], but neither have any appearance of stratification. Indeed the present bed differs from any the writer has observed in the Carboniferous rocks. It is like the waste known as "Blue Billy" from a chemical work. No Boulder-clay has been observed under any of these ash-beds, but if the coarse gravel this one contains is of the drift period the ash may be pre-glacial or perhaps of Tertiary age.

Mr. SMITH also read the following:—

5. On a Freshwater Limestone underlying a bed of Marine Limestone, near Paisley.

6. On the Boulder-clay at Hamilton Hill, N. side of Glasgow.

Several of the papers were illustrated by specimens, diagrams, and sections. Remarks on them were made by Dr. John Young, F.G.S., and other members.

Mr. JAMES NEILSON (Milnbank) read a paper on "The Society's Recent Excursion to the Parallel Roads of Glenroy," on 11th April, Spring Holiday, and stated that the members who had taken the trip had a very enjoyable and interesting day, of which he gave many particulars.

Mr. NEILSON also read "Additional Notes on Glenroy," in the course of which he enumerated several points where, he contended, previous writers had been at fault. Amongst these were the great mounds of debris, which had been called deltas, produced by the action of water, but which were really moraines, the result of ice-action.

These papers were illustrated by a large series of slides shown by the oxy-hydrogen lantern, from photographs by Mr. Robert Dunlop, *V.P.*, and by Mr. William Sinclair.

SOCIETY'S ROOMS, 207 BATH STREET, 26TH MAY, 1900.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

Mrs. Oswald Fergus, 12 Clairmont Gardens; Mr. John R. Campbell, 15 St. Vincent Place; Mr. Thomas Donald, 9 Leslie Street, Pollokshields; Mr. James H. Macintyre, 2 Victoria Gardens, Dowanhill; and Mr. Archibald Stewart were elected Ordinary Members.

Mr. GOODCHILD, F.G.S., Keeper of the Geological Survey Collection of Rocks and Fossils in the Museum of Science and Art, Edinburgh, read a paper entitled "The Dolerite of Aberdour, with some Speculations on the Origin of Eruptive Rocks in general." [For an Abstract see page 271.]

The paper was illustrated by diagrams and tables. An animated discussion followed, being taken part in by Dr. John Young, F.G.S., Messrs. Robert Dunlop, G. R. Thompson, Joseph Sommerville, James Neilson (Milnbank), Peter Macnair, the Chairman, and the author. Though generally admitting that intrusive igneous rocks might, in many instances, have acted replacively, most of the speakers expressed themselves as not prepared to adopt all Mr. Goodchild's views on the point, although admitting that they were well worthy of careful consideration.

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Mr. JOHN SMITH read a paper on "Palaeozoic Radiolarians, and Radiolarian Chert." [See page 245.]

He exhibited a large series of specimens of the radiolarian-bearing chert rocks, and under the microscope showed slides of the detached Radiolaria which he had found weathered out on Waterhead Hill, Leadhills, and on Sowan Dod, Wanlockhead, the latter 1784 feet above sea-level. Remarks on the specimens were made by Dr. John Young, F.G.S., and Mr. James Neilson (Milnbank).

Mr. ROBERT DUNLOP exhibited a splendid polished section of a Fossil Tree, *Lepidophloios*, on which the HON. SECRETARY read a Note, contributed by the Society's old and much-esteemed member, Mr. James Bennie, of the Geological Survey. [See page 263.]

Remarks on this fine specimen were made by several of the members.

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PROCEEDINGS FOR SESSION 1898-1899.

(41ST SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 13TH OCTOBER, 1898.

Mr. JOHN RENWICK, *Vice-President*, in the Chair.

Mr. J. B. MURDOCH, Hon. Secretary, exhibited specimens of Minerals from Gloucestershire, obtained at several of the excursions of the British Association during the recent meeting at Bristol.

1. Crystallised Calcite taken from strong veins passing through the Lower Carboniferous Limestones, worked for industrial purposes near Wickwar, about 18 miles N. of Bristol.

2. Gypsum from beds exposed in a fine section on the shore of the Severn, known as Aust Cliff, and a few miles N. of the great railway tunnel into Wales. These beds belong to the Keuper Marls of the Triassic rocks. Associated with them vertical strings and veins of gypsum also cross and ramify, evidently filling old cracks in the surrounding rocks.

3. Celestite (or Celestine of the older authors) from a curious surface deposit of the mineral near Totworth, and not far from Wickwar. Such deposits are characteristic of the Keuper Marls of the Bristol district which fringe the rim of the coalfield. The Celestite occurs in large nodular masses, and very irregular beds, which vary from 3 feet to 15 or even 18 feet in thickness, and is got just under the surface clay of a few feet in depth, the probe being used to find them. When located they are bared and worked opencast.

The exact conditions of the generally coarsely crystalline form of this mineral are not well understood, but it is believed that the Celestite was probably precipitated in an amorphous form, and that it afterwards seggregated in more or less crystalline masses. Chemically known as sulphate of strontium, it is used industrially in the beetroot sugar refineries in Germany and elsewhere. It combines chemically with the sugar and effects complete discolouration, after which it is supposed to be separated out; but the question remains whether the Celestite is all extracted, or whether some portion of it does not remain in combination and find its way to the teacup with what is known to us now-a-days as "pure cane sugar."

The CHAIRMAN (Mr. John Renwick, *V.P.*) read an interesting series of "Notes on the Society's Recent Excursion to the new Railway from Banavie to Fort-Augustus, Inverness-shire."

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A number of specimens of the rocks and boulders met with during the trip were exhibited.

Mr. WILLIAM SINCLAIR showed by the oxyhydrogen lantern a series of Photographs of the rock, hill, and river scenery taken by himself during the same excursion.

Mr. PETER MACNAIR read the summary of a paper, entitled "The Problem of the Marginal Highlands." [For an Abstract see page 273.]

The paper was illustrated by a large series of rock specimens, and by diagrams shown by limelight lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH NOVEMBER, 1898.

ANNUAL GENERAL BUSINESS MEETING.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

The Report of the Council for the past year (1897-1898) was read by the Hon. Secretary (Mr. J. B. Murdoch) as follows:—

REPORT OF THE COUNCIL FOR 1897-1898.

As on many former similar occasions the Council beg to submit to the members a Report on the work and progress of the Society during the past twelve months.

The MEMBERSHIP remains almost stationary, the hoped for increase in the roll not yet having taken place. The Council would still keep prominently before the members the fact that not only is an increase desirable but practicable, and that a slight effort on the part of each one would make it a reality.

The ASSOCIATE MEMBERSHIP—a comparatively new experiment in the Society's work—was very poorly represented last year, as only six students availed themselves of the very liberal terms offered. There is no doubt that the onerous examinations lately prescribed by the Science and Art Department have greatly discouraged geological students, one result being that a popular geological class, long carried on in Glasgow, had to be discontinued last winter from want of attendance. It is stated that recently these restrictions have been somewhat relaxed, which, it is hoped, will lead to an increase of students, and consequently of our associate members.

The FINANCES, which are in a sound condition, will be reported on by your Hon. Treasurer, Mr. John Wight, C.A.

The MEETINGS for the session were nine ordinary and two special meetings. The attendance at the former was good throughout and occasionally large; while the special meetings, held in the Large Hall at 207 Bath Street, drew crowded audiences, consisting, besides members and their friends, of members of other local scientific societies who were invited to be present.

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The PAPERS read at the meetings were twenty in number, mostly on West of Scotland subjects. At the two special meetings important papers were given by Dr. R. H. Traquair and Mr. Goodchild, each illustrated by an extensive series of limelight views.

SPECIMENS.—A considerable variety of specimens of minerals, rocks, and fossils were shown at the meetings, either as illustrative of papers or as separate exhibits, with notes. The Council look upon these as an important part of the Society's work, and in every way to be encouraged.

The EXCURSIONS of the season were twelve in all, and as in the previous year were carried on into August, an extension of time which seems to have suited the convenience of many members, as the attendance remained good to the last. [For a List of the Excursions see page 317.]

On the kind invitation of Mr. James Young, jun., contractor for the new Invergarry and Fort-Augustus Railway, an extended excursion was arranged to visit the new works on the line in August last, and was successfully carried out.

Notes and reports of a number of these excursions were submitted by their conductors at ensuing meetings, and the Council hope that this may become the established rule, as a good way of bringing many local points of interest before those members who are unfortunately unable to attend the excursions personally.

The LIBRARY has been largely used during the year, and a fair number of accessions to its shelves have been made by exchange or purchase. As it will be reported on by your Hon. Librarian, Mr. M'Lennan, more need not now be said.

A new supplementary catalogue of the books was printed and circulated during the year.

The TRANSACTIONS.—An important issue was made last May—Mr. John Smith's "Drift or Glacial Deposits of Ayrshire"—which the Council thought worthy of publication in its entirety as a supplementary part. Another part (vol. xi., part 2) is in preparation.

LOSS OF MEMBERS.—Since the last Report the Society has been unfortunate to lose several of its best-known members. Mr. Dugald Bell, F.G.S., who had filled the post of Hon. Secretary for some years, was an accomplished geologist, and, besides frequently filling the posts of Vice-President and Member of Council, was the author of numerous papers submitted to the meetings. No greater individual loss has been sustained by the Society than through the death of its accomplished late member, Mr. Bell. Another well-known member of long standing—Mr. John Kirsop—has been removed from amongst us this year. A frequent office-bearer, a constant attender of the meetings and excursions, an occasional contributor of papers, and a frequent exhibitor of specimens, Mr. Kirsop's genial presence will be much missed.

Sir James Bain, a prominent Glasgow citizen and one of its Lord Provosts, who is lately deceased, was for long a life-member of the Society, though it cannot be said that he took any active part in its work.

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The HON. TREASURER (Mr. John Wight, C.A.) submitted his Financial Statement. [For an Abstract of Accounts see page 320.]

The HON. LIBRARIAN (Mr. J. S. M'Lennan) read his Report upon the Library.

These Reports all showed a satisfactory state of the Society's affairs, and a hearty vote of thanks was awarded to the Hon. Secretaries, Treasurer, and Librarian.

Bailie Maclay was elected Vice-President, and Messrs. John Smith, James Anderson, Samuel Fingland, and R. W. Dron, members of Council, all for three years. Messrs. J. R. M'Farlane and G. R. Thompson were elected Auditors for the current year.

Mr. Colin Livingston, Fort-William, was elected a Corresponding Member.

Messrs. W. D. M. Falconer, C.E., James Street, Blairgowrie; David Murray, M.A., B.Sc., 5 Howard Park Drive, Kilmarnock; and David Nimmo, 17 Duke Street, Hamilton, were elected Ordinary Members.

Mr. JOHN SMITH exhibited specimens of Ancient Lead Slag from the moor between Leadhills and Crawfordjohn, Lanarkshire. This Slag, dark or yellowish in colour, is found on a patch entirely bare of vegetation, and from the large proportion of the mineral it still contains, evidently the site of a very ancient smelting. In parts it shows strongly iridescent colour on the surface. Charcoal frequently found shows that wood was used for reduction, though no trees now grow anywhere near. The date of these old works is merely conjectural.

Mr. SMITH also read a paper on "Detached Microliths from the Pitchstone Sill at Corriegills, Arran." [See page 275.]

The paper was illustrated by drawings of the microliths. At its close Dr. John Young, F.G.S., made some interesting remarks on the Arran Pitchstones, many of the flakes of which, he said, showed crowds of the most beautiful fernlike structures. He also gave some details of his method of preparing the pitchstone flakes for microscopic examination.

Mr. G. R. THOMPSON characterised the appearance of the microliths described by Mr. Smith as an extremely interesting one.

Mr. R. W. DRON, C.E., M.E., read a paper entitled "Notes on the Anthracite occurring at Provanhall, Lanarkshire, with an account of the Society's Recent Excursion." On 22nd October, by kind permission of Messrs. R. & J. Mather, the members of the Society visited Provanhall Colliery with the object of inspecting the seam of anthracite coal containing bands of shale altered into an impure graphite, and at present being worked. This seam, locally known as the "main coal," is generally bituminous, but here it has been much altered by two sheets of intrusive dolerite, one about 6 feet above and the other about 7 feet below the coal-seam. The anthracite coal has been rendered hard and brittle, with the characteristic steely-blue lustre, and contains over 90 per cent. of carbon. At one part of the coal-seam the action of the igneous rock was very clearly seen.

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Appearing first as a thin string with an inch or two of burnt coal above and below it, in the course of a few yards it thickened out until it replaced the whole seam of coal. The action of the dolerite on the bands of the adjacent carbonaceous shale has driven off all their volatile constituents, leaving behind only carbon and ash which vary in proportion in different parts of the workings.

The paper was illustrated by specimens of the rocks. In the subsequent discussion, taken part in by Mr. Joseph Sommerville, Mr. G. R. Thompson, and other members, some doubts were expressed as to whether the carbon of the shale mentioned by Mr. Dron was true graphite or not.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH DECEMBER, 1898.

Mr. ROBERT DUNLOP, *Vice-President*, in the Chair.

The following motion, proposed by Mr. JAMES NEILSON (Milnbank), was unanimously agreed to:—"That a sum not exceeding £10 of the Society's funds be devoted to Library purposes during the current session."

Mr. Thomas French, 1 Kelvinside Terrace, was elected a Life Member.

Mr. W. T. Brown, 260 Bath Street, and Mr. Robert Dick, Castlewood, Cathcart, were elected Ordinary Members.

Mrs. M'Lachlan, 5 Grosvenor Terrace; Mr. William F. Clark, 167 Crown Street; Mr. James Paterson Cree, Westfield, Rutherglen; Mr. T. M'Indoe M'Kenzie, Annfield, Larkhall; Mr. Andrew C. Mann, 30 Lansdowne Crescent; Mr. William Sommerville, 2 Millar Terrace; and Mr. George Wood, 17 Knowe Terrace, Pollokshields, were elected Associate Members.

Mr. GOODCHILD, F.G.S., of the Geological Survey, and Keeper of the Survey Collection in the Museum of Science and Art, Edinburgh, read a paper upon "Corals and Coral Reefs." [For an Abstract see page 277.]

The paper was illustrated by a large number of photographs thrown on the screen by the oxyhydrogen lantern and by a series of coloured drawings and diagrams.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH JANUARY, 1899.

Mr. JOHN RENWICK, *Vice-President*, in the Chair.

Mr. Mathew Borland, 150 Westmuir Street, Parkhead, and Mr. J. M. Mitchell, Auchengray, near Airdrie, were elected Ordinary Members.

Miss Margaret R. Niven, 3 Abbotsford Place, was elected an Associate Member.

The CHAIRMAN referred to the near departure of Mr. Robert Dunlop, Airdrie, for New Zealand, where he was to take charge of an important new industry. Mr. Dunlop was one of the Society's Vice-Presidents, and in the name of the Society he wished him all success in his new undertaking. Mr. Dunlop, who was present, briefly replied.

Mr. JOHN SMITH exhibited specimens of the Shale from which Gas was first made by William Murdock. He is said to have conducted his

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early experiments at Bell's Mill, near Lugar, the material used, and now exhibited, being a black and extremely tough bituminous shale, giving much ash. It occurs in connection with a band of stratified fossiliferous clay-ironstone, and is still used by the people of the district as fuel. There are two qualities, the best having been probably that used by Murdock, though to outward appearance there is very little difference.

Mr. JOHN SMITH exhibited specimens of Pitchstone from Corriegills, Arran, showing Starry Microliths on the surfaces of the rhyolitic planes, and visible to the naked eye. They are seen to be in abundance, and to radiate from a centre like the spokes of a wheel. On the columnar faces the microliths are also, though faintly, visible by the aid of a pocket lens, appearing more like the ends of the wheel-spokes. What caused this general orientation of these bodies is unknown, though magnetic influence might be suggested as a possible explanation.

Mr. GEORGE R. THOMPSON, Lecturer on Geology in the Technical College, read a paper on "The Microscopical Examination of Rocks." [For an Abstract see page 279.]

The paper was illustrated by numerous sections of the rocks thrown on the screen by the oxyhydrogen lantern, and by hand-specimens.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH FEBRUARY, 1899.

Bailie WILLIAM MACLAY, *Vice-President*, in the Chair.

Mr. Alexander T. Sinclair, Howard Villa, Maryhill, was elected an Ordinary Member.

Mr. JOHN SMITH exhibited specimens of Detached Crystals from White Trap, occurring at Dreghorn, Ayrshire. The matrix, originally a hard solid rock, with large conspicuous aggregations of crystals, has become so decomposed under exposure to the weather, that it falls into dust, leaving the crystals in a perfectly clean and sharp state. With further exposure the crystals themselves are reduced to fine powder. Their true composition has not yet been determined.

Mr. JOHN SMITH read a paper on "The Permian Outlier of the Snar Valley, Lanarkshire." [For an Abstract see page 250.]

It was illustrated by diagrams and specimens, and at its close a discussion was taken part in by several members.

Mr. JOHN BALLANTYNE, Rothesay, read a paper entitled "Notes on Excavations in the Raised Beach at the Rothesay Gasworks in 1896-1897. [For an Abstract see page 280.]

A large collection of the Post-glacial shells and boulders referred to were shown, also a number of diagrams. Some remarks were afterwards made by various members.

Mr. CHARLES R. COWIE read a paper on "The Glacial Phenomena of Loch Ranza Glen, Arran." [For an Abstract see page 282.]

A large series of lantern slides from photographs taken by Mr. Cowie, junior, to illustrate the paper were shown by limelight.

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SOCIETY'S ROOMS, 207 BATH STREET, 23RD FEBRUARY, 1899.

SPECIAL MEETING.

Bailie WILLIAM MACLAY, *Vice-President*, in the Chair.

Mr. JOHN HORNE, F.G.S., of H.M. Geological Survey, delivered a Lecture on "The Silurian Volcanic Rocks of the Southern Uplands of Scotland." [For an Abstract see page 285.]

The paper was illustrated by a large series of slides thrown on the screen by the oxyhydrogen lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MARCH, 1899.

Mr. JOHN RENWICK, *Vice-President*, in the Chair.

Mr. PETER MACNAIR exhibited a series of specimens of Plant-remains illustrative of the palæontology of the Giffnock Sandstones, and gave some explanatory notes upon them. [See page 223.]

Mr. J. B. MURDOCH, Hon. Secretary, exhibited specimens of Fossils from the Cordilleras of Peru, where his son had found them *in situ* at an elevation of 14,000 feet above sea-level. They were not yet identified, but were supposed to be of Tertiary age. The geology of the district appeared to be extremely puzzling, as besides metalliferous rocks, which contained almost all known minerals except tin, there were considerable coal-seams of good quality.

Mr. S. FINGLAND exhibited by the oxyhydrogen lantern a large series of Photographs, taken by himself at various excursions of the Society and at those of other local societies, and made some explanatory remarks.

Mr. JOHN SMITH read a paper on "Spango Granite." [See page 256.]

The paper was illustrated by drawings and by a number of specimens of the rocks of the locality.

Mr. PETER MACNAIR read a paper entitled "A still further Contribution towards the Solution of the Origin and Age of the Movements in the Giffnock and Bishopbriggs Sandstones." [See page 199.]

The paper was illustrated by a large number of diagrams and drawings.

SOCIETY'S ROOMS, 207 BATH STREET, 31ST MARCH, 1899.

SPECIAL MEETING.

Mr. J. BARCLAY MURDOCH, *Hon. Sec.*, in the Chair.

R. H. TRAQUAIR, M.D., LL.D., F.R.S., Keeper of the Natural History Collections in the Museum of Science and Art, Edinburgh, delivered a lecture on "Extinct Birds." [For an Abstract see page 287.]

The paper was illustrated by a large series of lantern slides shown by the oxyhydrogen lantern.

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SOCIETY'S ROOMS, 207 BATH STREET, 13TH APRIL, 1899.

Bailie WILLIAM MACLAY, *Vice-President*, in the Chair.

Mr. JOHN SMITH exhibited specimens from Ayrshire as follows:—

1. A bivalve shell from Waterland, Lugton, the interior filled half with limestone and half with calcite. After the lower half had been filled with the limey mud the rest of the cavity had been thickly coated with amorphous calcite and afterwards with crystalline calcite.

2. A Cement Nodule with minute Crystals of Galena, from Dockra Quarry, Beith. Similar nodules are known to occur in marine shale, where small deposits of the mineral sometimes are found in cracks, but Mr. Smith had not previously observed it in these nodules.

3. "Plasma" showing 88 minute faults, from Hacks, Kilwinning. The rock, which is light green in colour, is full of bands of deposition. It is traversed by lighter-coloured bands in which numerous curious faults, "steps," or "hitches," may be clearly noted.

Several explanatory diagrams were also shown.

Some Notes by Mr. G. R. THOMPSON on the Society's recent excursion to the People's Palace on 18th March were read by the Hon. Secretary. It was stated that the object of the excursion was to make an inspection of the Glen Collection of Rocks and Minerals and the Society's Collection of Rocks and Fossils, both recently acquired by the Corporation of Glasgow, and at present on exhibition at the People's Palace, Glasgow Green. The party was met by Mr. G. W. Ord, Curator of the Museum, who drew attention to many of the fine specimens exhibited, and explained the method he had adopted in their arrangement. The cases are placed in numerical order, and each contains a printed index to the specimens shown in it, which are indicated by numbers affixed to them. Case I. contains a splendid selection of glass models, while Case II. forms a general index to the whole collection, all the others containing merely an amplification, as it were, of the contents of No. II.

Mr. PETER MACNAIR read "Some Notes on the Society's Excursion to Callander, Perthshire," on 3rd April last, the annual Glasgow Spring Holiday, and of which he was conductor. He gave an interesting account of the various localities visited by the party, with a descriptive notice of the rocks met with, and their correlation with surrounding strata.

The paper was illustrated by diagrams and maps.

Mr. WILLIAM ARMOUR, C.E., read "Some Notes on the Society's Excursion to Dumbuck" on 8th April last, when the recently discovered Clyde "Crannog" was visited by the members.

Mr. W. A. DONNELLY, its discoverer, exhibited an extensive series on a large scale of Coloured Drawings of the "Crannog," done by himself, and described them in considerable detail.

A long and interesting discussion on the "Crannog" and its contents was afterwards taken part in by several of the members.

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SOCIETY'S ROOMS, 207 BATH STREET, 4TH MAY, 1899.

Mr. MATTHEW BLAIR, *Vice-President*, in the Chair.

Mr. William Pettigrew Ferguson, 135 Buchanan Street; Mr. Peter King, Mining Manager, Darngavel, Airdrie; Mr. W. M. Lockhart, Artist, 151 Sword Street, Dennistoun, were elected Ordinary Members.

The CHAIRMAN (Mr. Blair) exhibited a number of specimens which he had brought home after a recent visit to Egypt. These included:—

1. Mud Deposit of the Nile. 2. Coarse Desert Sand from Ridge of Ripple Marks. 3. Fine Desert Sand from Hollow of Ripple Marks. 4. Fossils from Nummulitic Limestone. 5. Petrified Wood. 6. Chipped Flints from the African Desert. 7. Syenitic Granite from First Nile Cataract. 8. Shelly Rock, from Jaffa. 9. Water of the Dead Sea (with Analysis).

Mr. Blair made a number of explanatory remarks on the specimens.

Mr. JOHN RENWICK, *V.P.*, read "Notes on the Society's Recent Excursion to Camelon and Falkirk," on 22nd April last, and of which he had been conductor. It was a joint one with the Edinburgh Geological Society, and the Glasgow Archæological Society, and consequently a large party assembled. After reaching Falkirk, the Parish Church, with its many interesting features, was visited, and then Bantaskine House and grounds. From this the members walked to Camelon, where the excavations recently made under the directions of the Society of Antiquaries of Scotland, to ascertain the site and extent of the Roman Station, were examined with much interest. Mr. MacLuckie, F.S.A.Scot., of Falkirk, acted as local archæological conductor, and Mr. B. N. Peach, of the Geological Survey, gave a short address on the salient geological features of the district. In the course of the afternoon a number of the members visited Callander House, and others walked along the line of the Roman Wall between Falkirk and Bonnybridge.

Remarks on points of interest were made by various members who had been present at the excursion.

"Some Notes on the Society's Excursion to Neilston," on 29th April, by Mr. James Anderson, the conductor, in his absence were read by the HON. SECRETARY (Mr. Murdoch), who supplemented them with some remarks of his own.

Mr. JOSEPH SOMMERVILLE also spoke of the interesting nature of some of the cuttings on the line of the new Lanarkshire and Ayrshire Railway, and a further excursion was suggested.

The CHAIRMAN (Mr. Matthew Blair, *V.P.*) read a paper entitled "Moraines and Deltas." [For an Abstract see page 289.]

The paper was illustrated by many photographs shown by the oxy-hydrogen lantern. An animated discussion on various points in it was taken part in by Messrs. John Smith, Charles R. Cowie, James Neilson (Milnbank), J. S. M'Lennan, and other members.

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SOCIETY'S ROOMS, 207 BATH STREET, 25TH MAY, 1899.

Mr. JOHN RENWICK, *Vice-President*, in the Chair.

Mr. John Gilbert Forbes, 52 Laurence Street, Partick; Mr. John Allan Martin, 1246 Dumbarton Road, Whiteinch; and Mr. Robert S. Young, 56 Mitchell Street, were elected Ordinary Members.

A paper on "The Old Volcanic Rocks of the Island of Arran," by Mr. William Gunn, F.G.S., of the Geological Survey, was read, owing to the author's absence, by the HON. SECRETARY (Mr. Murdoch). [See page 174.]

The paper was accompanied by a list of the fossils, and a number of specimens of the rocks and fossils were exhibited.

A paper entitled "Lord Dundonald, Ninth Earl, the Discoverer of Coal-gas as an Illuminant," by Mr. Robert Craig, of Beith, was, from the author's absence through illness, read by the HON. SECRETARY (Mr. Murdoch). [For an Abstract see page 290.]

Mr. JAMES WHITE read a paper on "The Distribution of Boulder-clay." He contended that the stiff, intractable deposit known as the "moraine profonde" of continental geologists, was wholly the product of glacier-ice. There was no room for doubt that the theory advanced by some authors of papers read in recent years before the Society, that Boulder-clay was a marine deposit, was entirely baseless.

The HON. SECRETARY (Mr. Murdoch), in the absence of the authors referred to, said in reply that the presence of marine organisms in Boulder-clay up to the height of 1100 feet above sea-level had been so clearly proved by Mr. John Smith, it was impossible to shake his evidence. At the same time it was evident that ice had played a considerable part in the arrangement of the materials of which Boulder-clay is composed.

Mr. PETER MACNAIR read a paper "On the Upper Silurian and Old Red Sandstone Rocks of Carmichael Burn, Lanarkshire, and their bearing upon the Origin of the Old Red Sandstone Question." In the course of his remarks he first referred to the views originally advanced by Sir Archibald Geikie to account for the puzzling section exposed in Carmichael Burn, in which palæontological principles had been wholly set aside, apparently, in favour of a stratigraphical succession, which was the outcome of the Director-General's theory that these rocks had been originally deposited in a land-locked basin. Mr. Macnair then gave what is now believed to be the true interpretation of this interesting section—that it was simply an anticlinal fold with a reversed fault or thrust, and proceeded to show its similarity to the one seen at the Hagshaws. He concluded by dealing with the evidence bearing on the physical conditions under which these rocks had been laid down, and maintained that it was quite inconsistent with any possible theory of their deposition in land-locked basins.

The paper was illustrated by maps and sections.

Mr. MACNAIR also read a paper by Mr. James Reid, Blairgowrie, and himself "On Certain Plant-remains from the Old Red Sandstone of Caith-

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ness." The authors first described *Zosterophyllum myretonanum*, from the Hill of Forss quarries near Thurso, and second, Plant-remains which were allied to *Lepidophloios*, *Lepidodendron*, *Sigillaria*, *Calamites*, and *Caulopteris*, from the Upper Flagstone group of Caithness. These remains were so obscure that it was impossible to attach specific names to them, while even their generic relationships were in many cases doubtful. They were now exhibited and described in the hope that better specimens might yet be obtained, when it might be possible to arrive at their exact affinities.

A number of specimens of the Plant-remains described in the paper were exhibited.

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EXCURSIONS FOR SEASON 1897.

To the Auld Wives' Lifts, Craigmaddie Moor, Stirlingshire, on Saturday, 20th March—Mr. John Renwick, conductor. Various theories have from time to time been put forward to account for the presence on a lonely moor of the enormous blocks of stone of which this famous cromlech is composed—human agency, ice carriage, or weathering. On the present occasion the opinion of members was divided on the subject. The distance walked was about 5 miles. [See *Trans.*, vol. xi., part 1, page 148.]

To Bowling, Dumbartonshire, on Saturday, 3rd April—Mr. James Neilson (Milnbank), conductor. Besides the contemporaneous and intrusive trap-rocks, the sandstones holding the cup and ring markings in Auchentorlie Glen were visited, and it was observed with regret that they were fast weathering. The walk was about 4 miles. [See *Trans.*, vol. xi., part 1, page 150.]

To Killin and Glen Ogle, Perthshire, on Monday, 19th April (the Spring Holiday—Mr. Peter Macnair, conductor. In the course of this whole-day excursion the party inspected the phyllites, grits, limestones, quartzites, mica-schists, and altered basic rocks of Loch Tay, Glen Ogle, and Lochearnhead. Some of the phenomena of the structure, succession, and metamorphism of the altered clastic rocks of the Southern Grampians were inspected. An examination was also made of the remarkable sill of altered basic rock which accompanies the Loch Tay limestone, and comes to the surface with it wherever it is exposed. [See Mr. Macnair's paper on the district, *Trans.*, vol x., part 2, page 302.] The party had tea at Lochearnhead. The distance walked was about 7 miles.

To Dalmeny and Cramond, Linlithgowshire, and Mid-Lothian—Mr. H. M. Cadell, F.G.S., conductor, a joint excursion with the Edinburgh Geological Society. The party inspected exposures of the calciferous sandstones, oil-shales, and intrusive traps. The remarkable "Eagle Rock," having a Roman "Eagle" carved on it, was seen, and also fine examples of the effects of sand-blast on hard rocks. The party had tea at Cramond Hotel. The distance walked was about 7 miles.

To Alexandra Park, Dennistoun, Glasgow, on Tuesday afternoon, 4th May—Mr. James Neilson (Milnbank), conductor. An inspection was made of the excavations for the new deep-level sewer in the district, and the fossiliferous shale of Carboniferous age taken from the tunnel was examined for specimens. [See *Trans.*, vol. xi., part 1, pages 147, 149.]

To Gourock and the Cloch, Renfrewshire, on Saturday, 8th May—Mr. James Steel, conductor. Amongst other objects of interest noted were the

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large numbers of carried boulders on the shore, the calciferous sandstones, trap dykes, and fossiliferous shales. The trip extended to about 7 miles.

To Darvel, Ayrshire, on Thursday, 20th May (the Queen's Birthday)—Mr. John Smith, conductor. During this whole-day excursion the members visited the great sand and gravel accumulations, a moraine, sand ridges, and the curious old dry channel of the Water of Irvine, locally known as the "Windy Wizzen." [See Mr. Smith's "Drift or Glacial Beds of Ayrshire," vol. xi., Supplement, page 60.] An exposure of Boulder-clay containing marine shells was also seen. The party had tea in the Turf Hotel, Darvel. The distance covered was about 7 miles.

To Auchenreoch and Murroch Glens, Dumbartonshire, on Saturday, 5th June—Mr. William Armour, C.E., conductor. These well-known glens contain some fine examples of river erosion, which were examined; also exposures of the calciferous sandstones, and of volcanic dykes intersecting them. The walk was from 6 to 7 miles for those who returned over Dumbarton Moor. [See *Trans.*, vol. xi., page 292.]

To Crofthead, Neilston, Renfrewshire, on Saturday, 12th June—Mr. John Mackie, M.E., conductor. The interesting new exposures of volcanic ashbeds interbedded with irregular layers of sand, at Crofthead Thread Works, were inspected, and the party afterwards visited the site of "The Ancient Lake of Cowdenglen," as described by the late Mr. James Bennie, of the Geological Survey, in the *Transactions*, vol. ix., part 1, page 213. [See *Trans.*, vol. xi., page 299.]

To Arthur's Seat, Edinburgh, on Saturday, 19th June—Mr. Goodchild, F.G.S., conductor. This was a joint excursion with the Edinburgh Geological Society. The sandstones of Salisbury Crags, and the overlying Ballagan beds, the lavas and tuffs of Whinny Hill, the volcanic rocks of various ages, the *roches moutonneés*, and other interesting features were examined in a walk of about 4 miles, after which the party took tea in the Royal Hotel, before the Glasgow contingent left for the west.

To Finnich Glen, Killearn, Stirlingshire, on Saturday, 7th August—Mr. J. C. Christie, F.G.S., conductor. The red sandstones, calciferous sandstones, and some fine examples of river erosion were examined in the course of the trip, which involved a walk of about 6 miles.

To Paduff Glen, Kilbirnie, Ayrshire, on Saturday, 21st August—Mr. John Smith, conductor. The principal points of attraction were the junction of the hill traps with the Carboniferous rocks, an ashbed in the Lower Carboniferous limestone, and a great exposure of *Productus giganteus* limestone. The walk extended to about 6 miles.

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EXCURSIONS FOR SEASON 1898.

To Troon, Ayrshire, on Saturday, 12th March—Mr. John Smith, conductor. The members visited the excavations which had been made for the New Dock, in the course of which a hone-stone bed was cut into, much resembling that on the Water of Ayr; also the workings of an old mine, from which at one time "China-clay" had been dug. [For a full account of the beds see *Trans.*, vol. xi., pages 238, 301.]

To Boylestone Quarry, Barrhead, Renfrewshire, on Saturday, 26th March—Mr. Joseph Sommerville, conductor. During the afternoon the calciferous sandstones were seen, and some glacial markings at Cross-stobs. From the contemporaneous traps of Boylestone Quarry specimens of analcite, prehnite, and native copper were obtained.

To Glen Roy, Inverness-shire, on Monday, 11th April (the Spring Holiday)—Mr. James Neilson (Milnbank), conductor. In this full-day excursion, a joint one with the Glasgow Natural History Society, the famous "Parallel Roads of Glen Roy" were inspected. [See *Trans.*, vol. viii., part 1, pages 40 and 72.] [See *Trans.*, vol. xi., page 302.]

To Giffnock, Renfrewshire, on Wednesday afternoon, 13th April—Mr. Joseph Sommerville, conductor. The thick-bedded sandstones,—the "Moor rock" and the "Liver rock"—were examined; also the annelid beds, and the Orchard limestone with its fossil-bearing shales.

To Ravensgill, Abingdon, Lanarkshire, on Saturday, 30th April—Mr. B. N. Peach, F.G.S., of the Geological Survey, conductor. This full-day excursion was taken jointly with the Edinburgh Geological Society, to visit the Lower Silurian rocks. The party examined the Arenig traps, the shelly mudstones, the radiolarian cherts, and the graptolitic shales. Tea was taken at Abingdon. The extent of the walk was from 6 to 7 miles.

To Giffnock, Renfrewshire, on Wednesday afternoon, 11th May—Mr. Peter Macnair, conductor. This second excursion to the locality this season was taken on purpose to talk over on the ground some differences of opinion as to the various phenomena shown in the Giffnock sandstone quarries. [See *Trans.*, vol. xi., page 199.]

To Kinghorn and Kirkcaldy Fifeshire, on Saturday, 14th May—Mr. Goodchild, F.G.S., of the Geological Survey, conductor. During this, a joint excursion with the Edinburgh Geological Society, the oil-shales belonging to the Lower Carboniferous formation, and the fossiliferous Yoredale (Hurlet limestone) series were examined; also the intrusive and contemporaneous eruptive rocks, of which there were fine exposures. Tea was had at Kirkcaldy. The walk extended to about 5 miles.

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To Ballochmyle and Barskimming, Ayrshire, on Thursday, 19th May (the Queen's Birthday)—Mr. John Smith, conductor. The purpose of this full-day excursion was to visit some of the Drift beds with marine shells, described by Mr. Smith in his paper on "The Drift or Glacial Beds of Ayrshire" (see *Trans.*, vol. xi., Supplement). The *Spirorbis* Carboniferous limestones were also seen, and traps and sandstones of New Red age. The party took tea at Mauchline. The distance walked was about 7 miles.

To the Pentland Hills, Mid-Lothian, on Saturday, 28th May—Mr. Goodchild, F.G.S., of the Geological Survey, conductor. This whole-day excursion was a joint one with the Edinburgh Geological Society. In the course of an interesting walk of from 6 to 9 miles, according to the route taken, the following rocks were examined:—Lower Carboniferous sandstones and shales, Old Red Sandstones and conglomerates, lavas and tuffs, Silurian greywackés, and fossiliferous argillites; also glacial markings, carried boulders, and moraines. The party took tea at Penicuik.

To the Kilpatrick Hills, Dumbartonshire, on Saturday, 11th June—Mr. John Renwick, conductor. The calciferous sandstone series and contemporaneous traps were inspected; also the tuff beds and underlying fossiliferous shales. The distance walked was about 6 miles.

To Tullich and Ben Reoch, Loch Long, Dumbartonshire, on Saturday, 25th June—Mr. William Armour, C.E., conductor. This was a joint excursion with the Glasgow Natural History Society to inspect some of the cuttings on the West Highland railway containing exposures of metamorphic rocks, felsite dykes, Boulder-clays, &c. The length of the walk was about 5 miles.

To Auchincruive, Ayrshire, on Saturday, 6th August—Mr. John Smith, conductor. The party on this joint excursion with the Glasgow Natural History Society inspected various exposures of the Coal-measure rocks, and of river drifts and terraces on the banks of the Water of Ayr.

To Devol's Glen, Port-Glasgow, Renfrewshire, on Saturday, 20th August—Mr. William Sinclair, conductor. Fine exposures of calciferous sandstone strata were seen; also contemporaneous eruptive rocks, and volcanic ash with ejected blocks. The total walk was about 3 miles.

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1897.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£145	0	0			
,, in Treasurer's hands,	6	0	1			
				£151	0	1
Life Members' Subscriptions,				15	15	0
Subscriptions for current year, and Arrears (£1 10s.),				74	0	0
Subscriptions in Advance,				1	0	0
Associate Subscriptions,				0	10	0
Interest on Funds,				8	13	0
Publications sold,				2	19	9
				£253	17	10

EXPENDITURE.

Printing *Transactions* and Papers,	£94	5	8					
Plates for do.,	11	0	4	£105	6	0		
Rent, Insurance, and Attendance,	£13	10	0					
Collector's Commission,	2	17	0					
Postages and Petty Expenses,	1	7	10					
Printing Circulars, etc.,	10	9	6					
Lantern Expenses,	0	10	0					
Disbursements by Secretaries,	6	13	3					
,, by Librarian,	1	19	9	37	7	4		
New Books,	£6	12	8					
Binding,	6	2	9	12	15	5		
Subscriptions to Palæontographical Society,				1	1	0		
Cash in Bank,	£95	0	0					
,, in Treasurer's hands,	2	8	1	97	8	1		
				£253	17	10		

STOCK ACCOUNT.

To Balance to credit,	£767	8	1	By Cash in Bank and on hand,			£97	8	1
				,, Funds Invested,			170	0	0
				,, Property—					
				Books,	£440	0	0		
				Furniture, Bookcases, and Microscope,	60	0	0	500	0	0
				Fossils, not valued.					
	£767	8	1				£767	8	1

GLASGOW, 28*th October*, 1897.—Examined and compared with Vouchers and found correct, the balance in Treasurer's hands being Two pounds eight shillings and one penny.

JOHN R. M'FARLANE, G. R. THOMPSON, } *Auditors.*

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1898.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£95	0	0			
,, in Treasurer's hands,	2	8	1			
				£97	8	1
Subscriptions for current year, and Arrears (£2 10s.),				69	0	0
New Members,				10	10	0
Associate Subscriptions,				0	17	6
Publications and Catalogues sold,				2	3	8
Interest on Funds,				7	2	1
Legacy from the estate of the late Sir Michael Connal, further to account, less duty,				1	2	6
Note.—The amount paid has been £7 10s., less duty, 15s.						
				£188	4	7

EXPENDITURE.

Printing New Volume and Papers,	£34	2	6					
Engraving Illustrations,	14	11	9	£48	14	3		
New Books,	£6	6	3					
Binding Books,	3	10	5	9	16	8		
Rent, Insurance, and Attendance,	£17	0	0					
Printing Circulars, etc.,	10	9	9					
Lantern Expenses,	1	11	9					
Collector's Commission,	3	0	0					
Postages, Stationery, and Petty Charges,	1	17	1					
Advertising,	2	7	6					
Disbursements by Secretaries,	6	15	8					
,, by Librarian,	1	13	8	44	15	5		
Cash in Bank,	£80	0	0					
,, in Treasurer's hands,	4	18	3	84	18	3		
				£188	4	7		

STOCK ACCOUNT.

To Unpaid Accounts for Printing,	£20	15	9	By Corporation Loan,	£170	0	0		
,, Balance to credit,	734	2	6	,, Cash in Bank and on hand,	84	18	3		
								£254	18	3
				,, Property—					
				Books,	£440	0	0		
				Furniture, Bookcases, and Microscope,	60	0	0	500	0	0
				Fossils, not valued.					
	£754	18	3					£754	18	3

GLASGOW, *4th November*, 1898.—Examined and compared with Vouchers and found correct, the balance in Treasurer's hands being Four pounds eighteen shillings and threepence.

JOHN R. M'FARLANE,
G. R. THOMPSON, } *Auditors.*

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